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ANALYSIS
OF A
COURSE OF LECTURES
ON
NATURAL AND EXPERIMENTAL
PHILOSOPHY,

VIZ.

1. MAGNETISM,
2. MECHANICS,
3. CHEMISTRY,
4 & 5. PNEUMATICS,
6. HYDROSTATICS,
7. ELECTRICITY,
8. FORTIFICATION,
9. OPTICS,
10. USE of the GLOBES, &c.
11 & 12. ASTRONOMY.

SIXTH EDITION.

By A. WALKER, *M. D. S.*

LECTURER on PHILOSOPHY to His Royal Highneſs the Duke of GLOCESTER; *Eton* and *Wincheſter* COLLEGES, &c.

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ADVERTISEMENT.

AS many who attend this courſe may not have made philoſophy a *previous ſtudy*, it may be ſuppoſed that many of its uſeful parts will eſcape the memory; 'tis therefore at the requeſt of *thoſe* I have drawn up this ſhort Analyſis; by a ſhort look at which any particular propoſition or experiment will eaſily be recollected.

ANALYSIS

OF

A Courſe of Lectures

ON

NATURAL AND EXPERIMENTAL

PHILOSOPHY.

LECTURE I.

On the general Properties of Matter.

AN hundred and fifty years are ſcarce elapſed ſince the clouds of prejudice, which had long overſpread the world, began to clear up, and men were convinced, by cultivating the ſciences and attending to nature, that no *fanciful conjectures* could ever lead them to the true cauſes of thoſe various phenomena that inceſſantly, and every where, meet the obſerver's eye; but that the narrow limits of the human underſtanding, confine the courſe of our reſearches to *one ſingle path*, namely, that of *experiment*, or the *uſe of our ſenſes*. Yet in this ſhort period, natural philoſophy hath riſen to an high pitch of improvement, and may with truth be ſaid to have made much greater advances towards perfection ſince the experimental method was introduced, than in the many ages before.

Becauſe many bodies are reducible to water, *this* element has been thought, by many able philoſophers, to be the primary origin of all matter; and that bodies differ only as they contain more or leſs *particles*, or *pores* differently diſpoſed. We find, indeed, the decompoſition of bodies finite, being unable to carry it beyond a certain limit; if we attempt to go further, we are always ſtopt by ſubſtances in which we can produce *no change*, which are incapable of being reſolved into others, and which ſtand as ſo many *firm barriers* obſtructing our progreſs. To theſe ſubſtances we affix therefore, more properly, the name of principles, or firſt elements, and they are *earth*, *air*, *fire*, and *water*.

The properties that are common to all theſe elements are, 1ſt. *Diviſibility*, *i. e.* the particles of each element are ſo ſmall that they eſcape the ſcrutiny of our beſt glaſſes. A candle will fill a ſphere of four miles in diameter with particles of light in a ſecond of time. Two ounces of aſſa fœtida, nicely weighed, may lie expoſed to the air, and have its particles carried off by it for a fortnight together, and yet it will not loſe the thouſandth part of a grain of its original weight. Eight grains of gold will cover a wire completely 13,000 yards in length. A grain of copper diſſolved in a jill of aqua fortis, will cover as much poliſhed iron with a fine ſkin of copper as the aqua fortis will wet: Nay, Lewenhock diſcovered with his microſcope more living animalculæ in the milt of one cod-fiſh, than there are men, women, and children on the whole earth.

2dly. The matter of which theſe elements are formed is *impenetrably hard*. If we pound the moſt brittle ſubſtance to the moſt impalpable powder its original particles ſtill remain unhurt. If water has no bed of air to fall upon, it will fall upon the glaſs in which it is incloſed like a piece of iron and make a loud click; a column of air falling on the plate of an air-pump will give a report as loud as a gun. Nay, elementary fire, ſubtil as it is, ſtrikes the bones, in the electric ſhock, like a ſolid body; and lightning penetrates the hardeſt ſubſtances.

3dly. Matter is *inert*, *i. e.* can neither move, nor ſtop, of itſelf. A ball on the whirling-table, neither begins to move when the table moves, nor ſtops when the motion of the table is ſtopped. Give a ſudden puſh to a bowl of water, and the fluid will fly over the bowl in a contrary direction; but if you turn ſwiftly round with the bowl in your hand, and ſtop ſuddenly, the water will fly over the bowl the way it was going. The *inertia* increaſes as the quantity of matter. A man lying with a large anvil on his breaſt, will not be hurt when a blackſmith ſtrikes upon it with a large hammer, with all his ſtrength; but if he had an anvil only a pound weight upon his breaſt, the firſt ſtroke of the blackſmith would kill him. The *vis inertiæ* of the large anvil makes its reſiſtance equal to the ſtroke of the hammer, ſo that the anvil may be ſaid to ſtrike the hammer as forcibly as the hammer ſtrikes it; and hence the difficulty of putting large bodies in motion. Theſe are but ſmall inſtances of thoſe three laws of nature which Sir Iſaac Newton found univerſal, viz. *That matter is perfectly indifferent to either reſt or motion.* 2dly. *That bodies move in proportion to the force that acts on them.* And 3dly. *That action and re-action are equal, and contrary.*

4thly. *Matter attracts, and is attracted*; *i. e.* All parts of matter have a tendency towards each other. A plumb line on the ſide of a mountain is drawn out of its perpendicular by the attraction of the mountain. Two cork balls, ſwimming on water, run together with an accelerated motion, and ſtick together. Water riſes above its level againſt the ſide of the bowl which holds it; and alſo in capillary or ſmall tubes: And hence the reaſon why water riſes in ſugar, ſand, between glaſs planes, up ſpunges, &c. for all theſe may be conceived as made up of capillary tubes. Two planes of lead, marble, glaſs, iron, &c. thruſt cloſe together, ſtick ſo that exceſſive force alone can ſeparate them. 'Tis this *attraction of coheſion* that makes all bodies cohere, or maintain any diſtinct form; and as ſome parts of matter attract more forcibly than others, iron comes to be heavier, and more compact, than wood; gold has more particles in leſs room than any other metal; lead is different from ſtone, becauſe its particles attract one another more forcibly; ſo that all that variety which we ſee in both mineral, animal, and vegetable ſubſtances, ariſes from the different combination of the four elements, the different degree of attraction in the particles of each, and in the different diſpoſition of the pores, or interſtices, that are between the particles of which they are compoſed. For the particles of the heavieſt and lighteſt bodies are all of the ſame weight, as may be proved by dropping a piece of gold, and a feather, down a tall glaſs that has no air in it to reſiſt their paſſage. Fire can deſtroy this coheſive quality in bodies, for a time, but makes no alteration in the original particles of bodies. It will inſinuate itſelf into gold, and ſeparate its particles, ſo as to make it into a fluid. Water and air are kept in a ſtate of fluidity by fire. Fire increaſes the repulſive qualities of all bodies. Metals ſwell with a ſmall degree of heat, as may be proved by the pyrometer. All nature is kept in motion by it; even blocks and ſtones ſwell by the heat of the day, and contract by the cold of the night. It gives water ſo repulſive a quality that it flies off in ſteam. Air is ſo ſwelled by it, that, to keep up its equilibrium, it is perpetually agitated by winds and ſtorms. Fire is the only *eſſential fluid*, and the cauſe of fluidity in other bodies, by ſeparating their parts. However there ſeems to be a repulſive quality common through nature, independently of fire. 'Tis ſaid, "where the ſphere of attraction ends, repulſion begins." The north pole of a magnet, at one tenth of an inch from a ſuſpended needle, attracts it; but at five tenths from it, it repels it. A glaſs tube rubbed with a dry hand, will alternately attract and repel feathers, leaf gold, and other light bodies. A ſmall needle will lie on the ſurface of water by its repulſion; flies run over it without wetting their feet, and a drop of oil will be ſuſtained by its repulſion without ever touching the ſurface of the water. The rays of light are ſaid to be repelled from the ſurface of a looking-glaſs, &c. however I doubt the univerſality of this principle.

5thly. *Elective attraction*, or the tendency which *one* part of matter has to unite with ſome or other *particular* part in preference to every other part of matter, forms the grand baſis of Chemiſtry.—Thus, water ruſhes into union with ſpirit, but not with oil.—Acids have the ſtrongeſt affinity to phlogiſton and alkali.—Air attracts water with greater avidity than ſalt, ſo that freſh water is abſorbed by it from the ſurface of a ſalt ſea, &c. Of the elective kind of attraction alſo is that of magnetiſm, becauſe it only attracts iron, ſteel, and itſelf; ſome hold magnetiſm and electricity as relations, becauſe ſteel ſtruck by lightning, or a ſtrong ſhock of electricity, acquires polarity and magnetic attraction. The loadſtone and iron are called male and female, becauſe of their likeneſs, and attracting nothing but one another. One Magnus, a ſhepherd, firſt diſcovered this wonderful ſtone from its ſticking to the iron in his ſandals, and from him it had its name: Its attraction is at two points, called its poles, and if the ſtone was broke into a thouſand pieces, each piece would have its attracting poles: This attraction is ſtrongeſt in contact, and diminiſhes by a proportion not yet found out, but that point of a ſtone which attracts one end of a touched needle, will repel the other. Flavius Gio, of Naples, about 350 years ago, firſt diſcovered that a piece of ſteel rubbed on it, and then ſuſpended, had the property of pointing north and ſouth, and thence applied it to navigation. An hundred years after it was found by Sebaſtion Cabot to have varied above 11 degrees eaſt. It continued to vary towards the eaſt at the rate of about one degree in ſeven years, till the needle formed an angle with the meridian of 30 degrees. It then returned towards the weſt at the ſame rate, ſo that about the year 1600 the line of *no variation* paſſed over England, the needle pointing then directly north and ſouth. Since that time it has continued varying towards the weſt, and with us at this time the needle is 22 degrees 48 minutes weſt. It is probable it will continue to vary weſtward till it makes an angle with the meridian of 30 degrees, (as it did at its eaſtern extremity) and then return weſtward, finiſhing its revolution in between 900 and 1000 years. A line of no variation at preſent paſſes ſouthward near Madagaſcar, doubles the Cape of Good Hope, ſlopes acroſs the Atlantic, touching Brazil, and ſerpentine paſſes through Canada.

The theory of making *artificial magnets* is derived from an *effluvium* ſuppoſed to flow from one pole of the magnet to the other, and *vice verſa*—the exiſtence of which is made very probable, by ſteel filings ſcattered over a plate of window glaſs, with a *bar magnet* under it, when the effluvium in its paſſage from one pole to the other influences the filings into many parallel and beautiful curves. Two pieces of ſteel, *ſpring temper*, made in ſhape of horſe-ſhoes, and their ends put together; if then two *bar magnets* juſt ſeparated and of oppoſite poles, or an *horſe-ſhoe* or *natural* magnet be rubbed over them all the ſame way, *polarity* and *attraction* will be communicated to the ſteel; but if the two pieces be put together, and the two repelling ones together, they attract ſtrongly: And hence ſeveral bars thus united form a very ſtrong magnet.—Hang a piece of iron as a *conductor* between the two poles, and the magnet will long retain its virtue, particularly if it hangs ſo as it can turn north and ſouth.—Lay four ſmall bars of ſteel touching one another in a line, lengthwiſe; ſlide one pole of a magnet from the right hand to the left over them ſeveral times, and they will be good magnets: But if then you ſlide the ſame pole over them from the left hand to the right, the magnetic virtue will be entirely taken from them. *Fire* and *ruſt* deſtroy the power of theſe magnets, and time will weaken them, if a conductor of iron or ſteel do not form a magnetic circuit for the effluvium to paſs through. To recal the decreaſed virtue of a magnet, hang a large *ſand bag* to the iron adhering to it, and keep every day increaſing the ſand.—To give the virtue to a *knife*, draw it over either pole from hilt to point ſeveral times.

By fire, is underſtood a complex idea of ſomething *red, ſhining, that excites the ſenſation of heat, and rarefies or expands all known bodies.* It is the moſt powerful agent in the decompoſition of bodies. It is the only *eſſential fluid* in nature, and the cauſe of fluidity in other bodies, by ſeparating their parts; hence even air itſelf becomes ſolid when deprived of the fire it contains, as bodies of the moſt difficult fuſion become fluid when penetrated by a ſufficient quantity of the particles of fire. *All* bodies become hot by the approach of ignited bodies, and by friction; but bodies that contain a ſufficient quantity of phlogiſton, *only*, are capable of inflammation. Phlogiſton is not fire, but the principal of inflammability; *i. e.* when it is combined with various ſubſtances in due proportion, it renders them inflammable. Phlogiſton may be ſeparated from one body, and given to another; hence an inflammable body may be

deprived

deprived of its inflammability, and a body naturally not inflammable, may be rendered ſo by combining it with a ſufficient quantity of phlogiſton. When expelled from bodies it is not annihilated—it only eſcapes from the burning body into air, which gives proof of its having acquired it, and is then ſaid to be *phlogiſticated*; and hence no inflammation will take place but in the common air. Combuſtion ceaſes when the air ſurrounding the burning body is filled with phlogiſton---hence a fire is put out by blowing phlogiſticated air into it ---but enlivened by a current of freſh air. All bodies contain more or leſs of this wonderful principle---for all bodies grow hot by violent friction; friction may be therefore ſaid to be a kind of *fire-pump*, that draws latent fire from the adjoining bodies to the place where the friction is going on, and ſtrongly indicates that phlogiſton may lie in a concrete form in, and be a conſtituent part of all bodies; nay, *Birgman* ſays, 100 ounces of charcoal contains 99 ounces of phlogiſton, and but one of earth; and yet he affirms that phlogiſton is the cauſe of volatility, as metals deprived of their phlogiſton are heavier as a calcs than as a metal; inflammable air is eight or ten times lighter than common air, &c. So little do we know of fire, that any attempt at a theory of it muſt appear preſumptuous and premature; we find however that *light*, *heat*, and *electric fluid* have ſo many qualities in common with *phlogiſton*, that hereafter it may probably be found they are all but modifications of the ſame principle. Rubbing, or friction, in *all* bodies produce *heat* and *electricity*, and both theſe dilate bodies, help vegetation, germination, evaporation, motion of the blood, the growth of the fetus, and the hatching of eggs. Heat and electricity both reduce, and melt metals; and bodies that receive *heat* with difficulty receive *electricity* ſo, &c. May not the rays of the ſun be diluted phlogiſton? May not the velocity with which they proceed from the ſun prevent their abſorption by the air, in their paſſage through it? and as all bodies have more or leſs affinity to phlogiſton, may not this diluted phlogiſton be abſorbed by various bodies, and lie in a concrete form in them till called forth from them by friction or combuſtion? Experiments that favour this hypotheſis are, 1ſt. Rays collected in the focus of a burning glaſs, produce on opaque bodies the moſt intenſe heat that is producible by the art of man. 2d. Living vegetables imbibe phlogiſton (as nutrition) from the air, and part with it back again into the air in the act of combuſtion, boiling, or putrefaction; (for rotten wood, putrid fiſh, ignis fatui; indeed all animal and vegetable ſubſtances are luminous while decompounding by putrefaction)—which is but parting with the *inflammable principle* that was a conſtituent part of theſe bodies while in health. 3d. Bodies in the act of *delivering* phlogiſton to the air, or any other affinitive menſtruum are *univerſally hot*;—hence the heat of a common fire, where phlogiſton is transferring from the coals to the air, inflamed gunpowder, &c.—The *heat* of effervеſcent mixtures, ſuch as diluted vitriolic acid, and iron filings:---Copper and diluted nitrous acid:---Iron filings, water, and ſulphur:---Air carrying off phlogiſton from the lungs in the act of reſpiration, and thereby producing animal heat: Pyrites and water producing the heat of the bath waters, &c. which is but the water ſeizing the vitriolic acid, and thereby expelling the phlogiſton of the acid into the air, for a mixture of vitriolic acid and water always produce an intenſe heat:---The production of fire by the eſcape of phlogiſton from phoſphorus, pyrophorus, &c. when expoſed to the air is another inſtance:---and the aſtoniſhing flame ariſing from oil of turpentine when a mixture of vitriolic and nitrous acid is poured upon it, alarms, while it proves, that air is the natural menſtruum of phlogiſton, and that inflammation will not take place except in common air. 4th. A fire-brand expoſed in dephlogiſticated air blazes out with a vivid flame, while the air ſeizes its phlogiſton. 5th. Metals calcine but partially in ſmall quantities of confined air, that air is ſo ſoon ſaturated with phlogiſton;---a current of air muſt paſs over melting metals or they will not calcine:---Air ſo expoſed becomes phlogiſticated and diminiſhed. 6th. Metals reduced to a calcs by calcination, or by a ſolution in acids, part with their phlogiſton during the proceſs; and a calcs expoſed in inflammable air, and heated by the focus of a burning lens, imbibes or ſwallows up the inflammable air, and revives into a perfect metal!---This extraordinary fact ſhews, that metals may as it were be taken in pieces and put together again—for if the phlogiſton that flies off from a calcining metal could be preſerved, and the calcs of that metal be heated in it, the calcs would ſeize the phlogiſton it had loſt, and become the very ſame metal it was before the proceſs. Hence we have reaſon to believe that inflammable air is the true *elementary phlogiſton*, and that it is this gas in a concrete ſtate in coals, candles, wood, metals, &c. that makes them inflammable. Phlogiſton in an active ſtate produces *heat*---approaching to a latent ſtate, *cold*. Hence the evaporation of volatile ſpirits; the mixture of ſalt and ſnow---and ſnow and ſpirit of nitre, ſerve to concentrate or deaden the action of phlogiſton,---and by theſe mixtures in cold weather and cold climates, quickſilver has been frozen into a ſolid metal.

LECTURE II.

MECHANICS.

THE *attraction of gravitation* is the weight of bodies, or that tendency which matter has towards the centre: By this power the earth is formed into a denſe ball, and every thing that lives upon it held faſt to its ſurface. A body left to the power of this agent falls about a rood in the firſt ſecond of time; three roods in the ſecond ſecond; five in the third; ſeven in the fourth, &c. agreeably to the odd numbers 1, 3, 5, 7, 9, 11, 13, &c. For the *vis inertiæ* of the falling body, added to the power of gravity in every ſucceeding ſecond, accelerates it, as the ſquares of the times. Thus,—at the end of the 4th ſecond the body has fallen about 16 roods,---at the end of the 6th ſecond it has deſcended 36 roods, &c. This is proved by a projected ball falling from an horizontal line one inch in the ſame time in which it falls 3, 5, 7, &c. inches in the ſucceeding times; and by the ſuſpenſion of unequal weights over a pulley. Hence we find this power of gravity decreaſes as the ſquares of the diſtances increaſe, (i. e. a ball, which weighs 9 lb. on the earth's ſurface, would weigh only 1 lb. at three ſemi-diameters of the earth above it.) For it is found that the moon falls from a tangent to her orbit in this proportion; ſhewing that ſhe is actuated by the ſame law that makes a pebble deſcribe a curve when it is thrown from a ſling. For that pebble, if it was projected with proper force, and had a vacuum to move through, as the moon has, would go round the earth for ever as ſhe does.

Motion is rectilineal; *i. e.* all bodies put in motion by *one* force, endeavour to go off in a ſtraight line. Hence, if a coach in ſwift motion be turned ſuddenly, it overſets by endeavouring to go off ſtraight: But if a body be impreſſed by *two* forces, in oblique directions, it will obey neither, but go the diagonal of the ſquare. Hence a ball dropt from the maſt head of a ſhip, under ſwift ſail, falls on the deck as if the ſhip was at anchor: And a ball ſhot horizontally from a tall tower, obeys neither the powder nor its own weight, but comes to the ground in a curve formed of the two. We ſhall in due time ſee that the planets move by this wonderful law.

The momentum of a falling body is as the ſquare root of its height. Ex. Hang a pound weight on one end of a ſcale-beam, and if at the other end you let fall a certain weight from the height of one foot, it will juſt lift, or cant the pound up: But if you let the ſame weight fall four feet, on one end of the ſcale-beam, it will cant up two pounds weight hung at the other. If it falls nine feet, it will lift up three pounds weight at the other, &c.

Fluids ſpout by the ſame law. A pipe of the ſame bore as another, but four times as far below the ſurface of the water in a ciſtern, diſcharges twice as much as the upper one; if it be ſixteen times as far beneath the ſurface, it will diſcharge four times as much as the upper one, &c. For the velocity with which a fluid ſpouts, at any depth below the ſurface, is equal to that which a body let fall *that height* would acquire.

The *momentum*, or force, of a body, ariſes from its quantity of matter being multiplied into the velocity with which it moves: Thus, if a *battering ram* be 1000lb. weight, and the velocity with which it ſtrikes a wall be 20, then is its *momentum* 20,000: But a cannon ball ſhall do the ſame execution, if its quantity of matter be no more than 10lb, provided it be thrown with a velocity equal to 2000, for 10×2000=20,000, ſo that the *momentum* of both are equal. This may eaſily be proved, by laying 2 lb. weight upon *a ſpring*; if it throws it one yard, it will throw 1 lb. two yards: And 8 lb. will be counterpoiſed by 4 lb. if it be hung on a balance at *twice* the diſtance from the fulcrum. Hence the force, or power, of any machine, whether ſimple or compound, is eaſily computed; for when two bodies are ſuſpended upon any machine, ſo as to act againſt one another, if the perpendicular *aſcent* of one body, be to the perpendicular *deſcent* of the other in the inverſe ratio of their weights, they will balance one another; and therefore ſo much quicker as the power moves than the weight, ſo much is the advantage gained by the machine, and gives this mechanical anxiom, "That what is gained in power, by any machine, is loſt in time of working it." *Sir Iſaac Newton's.*

All kinds of mechanical engines conſiſt, more or leſs, of theſe *ſix powers*, viz. the *lever*, the *wheel* and *axle*, the *ſyſtem of pullies*, the *inclined plane*, the *wedge*, and the *ſcrew*.

The *lever* is a bar of wood, or metal, turning upon a prop, or centre, (commonly called the *fulcrum)* and is uſed either to raiſe weights or overcome reſiſtances. There are three kinds of levers, and in each of them, the velocity of each point is directly as its diſtance from the prop. When this *prop* is between the *weight* and the *power*, 'tis called a *lever of the firſt kind*; and ſo much as the power is further from the prop than the weight, ſo much is the advantage gained by the power over the weight. *Iron crows*, *ſciſſars*, *pincers*, *rudders of ſhips*, *&c.* are *levers of the firſt kind.* *A lever of the ſecond kind*, is when the *weight*, or *reſiſtance*, is between the *prop* and the *power*, as in doors turning on hinges, knives that turn on a centre at the point, oars, *&c. A lever of the third kind*, is when the *power* is applied between the *weight* and the *prop*, as in rearing a ladder againſt the wall; moving our legs and arms by the power of the muſcles, &c. The *bended lever* differs in nothing from one of the *firſt kind*, but in form, 'tis like a hammer drawing a nail. In each of theſe levers, ſo much as the *power* moves farther, or ſhorter than the weight, ſo is the advantage, or diſadvantage, of each. The power of a *compound lever* is found by multiplying the power of each into one another.

In the *wheel and axle*, the advantage of the *wheel* over the *axle*, is as their diameters, i. e. if the *wheel* be four times as large as the *axle*, a man may lift four times as much by it, as by his own ſtrength, allowing for friction. This *power* is the principal part of a common *crane*.

Upper pullies that are fixed, only ſerve to change the direction of the power, and give no mechanical advantage thereto: But the under block of pullies, moving with the weight, give an advantage proportionate to the number of ropes, by which the weight is ſuſtained; and which may be eſtimated alſo by ſo much as the power moves faſter than the weight. A *running pulley* doubles whatever advantage was gained by the other parts of a machine before it was applied, always allowing for friction, which in pullies is very great.

The *wedge* ſeparates heavy, or cohering bodies, with a force proportioned, *as the thickneſs of its back is to the length*; i. e. if its back be one foot, and the length twelve feet; then may the momentum of the ſtroke which moves the wedge be one twelfth only of the weight, or cohering force, of the parts to be ſeparated.

The *inclined plane* is half a wedge, and therefore its power is, *as its length is to its height*; i. e. I ſhall roll a cylinder up an inclined road of twenty yards in length, and but one yard perpendicular height, with one twentieth part of the force that would be neceſſary to lift it perpendicularly that yard.

The *ſcrew* may be conſidered as an inclined plane wrapt round a cylinder; therefore as the power moves round the cylinder, while the weight riſes, the power has an advantage over the weight, as the length of one thread round the cylinder, is to the diſtance of one thread from another; or as the velocity of the power is to the velocity of the weight.

In a *common jack* we have all theſe powers together, if to an arm of the fly the power be applied; and ſo far as that power moves farther than the weight, ſo much is the advantage which the power has over the weight.

If machines could be made to move without *friction*, the leaſt degree of power added to that which balances the weight would be ſufficient to raiſe it: But as the ſmootheſt bodies are full of pores, and little eminences, theſe will lock into one another in rubbing bodies, and greatly retard the motion of a machine. The friction in the *lever*, and in the *wheel* and *axle*, is very ſmall: In *pullies* it is very conſiderable: But in the *inclined plane*, the *wedge*, and the *ſcrew*, it is very great. The allowance made for friction in machines conſiſting of ſeveral of the mechanic powers, is uſually *one third*; i. e. after calculating all the ſingle powers as above, and multiplying theſe into one another, from the laſt product I deduct one third of it, and the remainder is the true momentum or force of the machine. Friction is of two kinds: The *rubbing friction*, and the *friction by contact*; the rubbing of the locked wheel of a coach againſt the road may repreſent the *firſt*; and the manner of its touching the road in its uſual motion the *ſecond*. When the *firſt* kind of friction can be reduced to the *ſecond*, there is a manifeſt advantage given to the power of the machine, as is demonſtrated by the experiments with the friction wheels. Theſe wheels are hung ſo that their peripheries form an angle, in which the gudgeon of the heavy wheel turns. *Water wheels*, large *grinding ſtones*, and even *wheel carriages*, are hung in this way at a ſmall expence; but being apt to wear out very faſt, they are better fitted to ſmall weights, moving with great velocity. And hence the friction balls in wheel carriages, cranes, &c. become ſoon uſeleſs. A *narrow* rubbing ſurface has much the advantage over a *broad* one, though they each ſuſtain the ſame weight, becauſe of fewer points and pores being in contact; hence the ſmaller the gudgeon or axle of a wheel the better, if it has but ſtrength to ſupport the weight. The friction in water that carries an under-ſhot mill, is much taken off by a ſloping pedal; the velocity of the float-boards of the wheel ought to be one third of the velocity of the water; the number of ſtaves in the trundle, ought to be no even part of the number of coggs in the wheel that turns it; and the grinding ſtone ſhould not make above 60 revolutions in a minute.

Beſides the *mechanic powers*, and various inſtruments to explain *friction*, momentum, falling bodies, &c. the machines uſed to illuſtrate this lecture are, 1ſt. A moveable crane. 2d. A mill to ſaw marble. 3d. Ditto to ſaw timber. 4th. A common pile-driver. 5th. Voulou's pile-driver. 6th. The equable moving wind-mill, that cloaths, uncloaths, and turns itſelf to the wind. 7th. Drill-ploughs. 8th. Ventilators. 9th. Wheel carriages. 10th. Methods uſed in moving the great ſtone on which the ſtatue of Peter the Great is erected in Peterſburg.

11th. A compleat fortification. 12th. Boulton, Blakey, Smeaton's and the common fire or ſteam engines. 13th. Water engines of all denominations, viz. common pumps, forcing pumps, rope pump, Archimedes's ſcrew pump; bucket engines, machines for draining, embanking, &c.

LECTURE III.

PRINCIPLES of CHEMISTRY.

ALL bodies exiſting on the earth may be arranged under three heads, viz. the *animal*, *vegetable*, and *mineral* kingdoms. The firſt comprehends all bodies endowed with life and ſelf-motion. The ſecond, thoſe which have life only, the power of growing, and propagating their ſpecies. The third, all bodies deſtitute of life and ſelf-motion. Bodies are alſo conſidered as *ſimple* or *compound*.---Simple bodies are ſuch as cannot be reſolved into any thing more ſimple, ſuch as pure earth, pure water, &c. Compound bodies conſiſt of two or more of the primary elements, ſuch as an *animal body*, for earthy particles and various fluids form its compoſition. That branch of philoſophy which examines the properties of theſe bodies, by compounding or decompounding them, is called CHEMISTRY.---A branch ſo extenſive and important, that the ſuſtenance of life---the arts and ſciences---various manufactories---nay, even trade and commerce depend upon a continual *compoſition* and *decompoſition* of natural bodies.

SOLUTION is a property of *fluids*, whereby they imbibe (or incorporate themſelves with) *ſolids*, by ſeparating their parts.--The ſea is a ſolution of ſalt in freſh water. Ink is a ſolution of vitriol and galls in water. Diluted nitrous acid diſſolves copper; when the ebullition is over, the liquor will be a ſolution of copper. Diluted vitriolic acid in like manner gives a ſolution of iron. Quickſilver diſſolves lead, tin, &c. Gold diſſolved in aqua regia is a ſolution of gold, &c. and camphor in like manner is diſſolved in ſpirit of wine, &c.---Solutions in water, ſpirits, acids, air, &c. are tranſparent---but mixtures are muddy or opaque.

DISTILLATION is the application of heat to ſeparate fluid and volatile parts from bodies; and to collect them in other veſſels by means of cold. Heat expands all bodies, and puts their particles into a repulſive ſtate; when this application becomes more powerful than the coheſion of the body, a decompoſition takes place. Sea water put in a retort, and expoſed to the fire, the water ſoon riſes in the character of ſteam---this ſteam paſſing through a cold pipe is condenſed, and brought back again into water, but freſh, and the ſalts being leſs volatile, remain at the bottom of the retort. Liquors that have gone through a ſtate of vinous fermentation, are diſpoſed to part with ſpirit---and ſpirit riſing in ſteam with leſs degree of heat than water, a ſeparation of the two is eaſily effected in a ſtill, by tempering the fire,—hence the ſteam of the ſpirit paſſing through a long ſpiral pipe (immerſed in cold water) is condenſed:---when the ſpirit is all come over, the water begins to riſe in ſteam, and may be received in a ſeparate veſſel---the earthy and and colouring particles of the wine will at laſt be found dry at the bottom of the ſtill.

SUBLIMATION is but a diſtillation of dry ſubſtances. *Sulphur* expoſed in a ſubliming veſſel, is melted with a very gentle heat, and riſes in ſteam, forming flowers of ſulphur on the ſides and top of the veſſel, and is but the ſame ſulphur that was melted. *Gum benzoin* melted within a tall a tall receiver, with a ſprig of roſemary in it, riſes and forms an hoar-froſt appearance on the leaves of the roſemary.—*Phoſphorus* juſt covered with water, in a Florence flaſk expoſed over a lamp, ſublimes into the appearances of ſtars, and the aurora borealis. It riſes with the ſteam of the water, and ſtruggling to obtain the air, its menſtruum forms beautiful coruſcations in the flaſk, particularly when ſeparated from the lamp, and expoſed in the dark.

PRECIPITATION is performed in fluid matters only---it is a diſuniting of two or more ingredients by the addition of another, which by its greater affinity, unites with one of the ingredients, and ſeparates the others from it, and by which they generally fall to the bottom of the liquor. Copper diſſolved in diluted nitrous acid, is precipitated by iron---much of the diſſolved copper becomes revived by the phlogiſton of the iron, and form a ſkin of copper on the iron; the reſt falls to the bottom of the liquor precipitated, &c. &c.

SATURATION ſignifies the point at which the attractive and diſſolving power of any menſtruum ſtops, when filled with the matter it is to diſſolve.—Solutions of ſalt or ſugar in water; of ſulphur in oil of turpentine; camphor in ſpirit of wine; ſilver in aqua fortis; water in air, &c. are tranſparent till fully ſaturated; if more be added, they ſink, in their natural form, to the bottom, undiſſolved, and the menſtruum is ſaid to be fully ſaturated. If water, ſpirits, oil, &c. be evaporated from the matter with which they are ſaturated, the matter aſſumes its natural form; --- common ſalt will aſſume a cubical form; ſalt-petre the form of a priſm, &c. &c. adhering to the bottom and ſides of the containing veſſel.

AFFINITY. This term is of great extent in chemiſtry, and ſignifies *the tendency which the conſtituent parts of bodies have to unite readily with* SOME *ſubſtances in preference to others.* Water and vinegar have affinity, becauſe they are eaſily mixed together. Water and oil have no affinity becauſe they will not mix, but ſhew a kind of repulſion to one another. If a mixture, A and B, have a third matter, C, added to them, to which A has a greater attraction or affinity than to B, then will A let go B, and join in union with C, and B is precipitated. Ex. 1ſt. Solution of ſublimate mixt with oil of tartar, produces an orange coagulum; an acid (as the ſpirit of nitre) added, ſeizes the oil of tartar, (as an alkali, to which it has a ſtrong affinity) the colour is diſcharged, and the liquor becomes pelucid. 2d. Solution of blue vitriol mixt with ſpirit of ſal ammoniac, produces a blue-coloured alkaline liquor. The nitrous acid, added, ſeizes the ſal ammoniac as an alkali, diſcharges the colour, and the liquor becomes acid; if then an alkali be made predominant (as oil of tartar) the fine blue is again reſtored. 3d. Acid ſolutions are detected by ſyrup of violets, which turns them red: but the ſame ſyrup turns an alkaline ſolution green. Hence red or blue flowers ſteeped in acid water, impart their colouring particles to the water, which becomes red: oil of tartar added, turns it green. 4th. Salts inſtantaneouſly chryſtalize when ſpirit of wine is added to their ſolution in water,---becauſe ſpirit and water have a greater affinity to one another than ſalt and water. 5th. Inflammable air is not inflammable of itſelf, any more than fixt air is efferveſcent; but it is a conſtituent part of a compound, which being let looſe, cauſes by its flight the phænomenon of inflammation. Hence phoſphorus (as a mine of phlogiſton) when rubbed between the folds of brown paper to increaſe its ſurface, takes fire, ſo ſoon as it becomes opened out to the air. 6th. Two thirds of nitrous acid and one third vitriolic acid mixed, and then poured on the oil of turpentine, produces inſtant and tremendous inflammation! 7th. Ether dropt on water produces ice. 8th. Calcs's are revived, if while they are in fuſion, inflammable air be blown upon them. 9th. Equal quantities of regulus of cobalt diſſolved in diluted nitrous acid, and ſea-ſalt diſſolved in water, make an ink that comes and goes with heat and moiſture. 10th. Inviſible writing, with a ſolution of ſugar of lead, is rendered black by a ſolution of liver of ſulphur, both in water. This phlogiſtic effect will take place through a thick book, or even a ſtone wall. 11th. Hemberg's pyrophorus requires one part ſugar and three parts allum, to be melted, ſtirred, and dried on an iron ſhovel till it becomes a blackiſh coal; then bruiſe it into powder, and put it into a long-necked bottle, and the bottle into a crucible filled with dry ſand; then place the crucible in a gradual fire, till the whole becomes red hot, and keep it ſo an hour, or till a weak ſulphurous flame has iſſued out of the bottle's neck a quarter of an hour; remove it by degrees, and cork up the bottle as ſoon as it will not burn it, or decant the pyrophorus into a dry bottle, well ſtopped from air. A little of this powder expoſed to moiſt air on brown paper, inſtantly takes fire. 12th. Vitriolic acid contains much phlogiſton, diluted with water, it becomes diſpoſed to part with it to the air, which decompoſition always produces *heat*. Hence iron pyrites lying in water produces heat, and becomes ink with an infuſion of galls; rain water running over quarries of ſuch pyrites above Bath, acquire the heat for which thoſe waters are ſo celebrated. 13th. Vegetables contain much nitre; the water therefore in which potatoes, ſpinage, &c. are boiled diſſolves the nitre, and hence brown paper ſoaked in ſuch water, becomes excellent *match* when cut in ſlips and dried. 14th. Silver diſſolved in diluted nitrous acid, (or luna cornea) is precipitated by copper;

for the acid has a greater affinity to copper than ſilver; therefore the ſilver precipitates, and form thoſe beautiful ramifications called the arbor Diana.

ACIDS are both in a liquid and concrete form, have a ſour taſte, and they effervefce with alkalies. *Vitriolic acid* is fluid, tranſparent, colourleſs, and without ſmell, like water, but much heavier: It is got generally from ſulphur, by diſtillation with water, to which it has great affinity.—*Nitrous acid* is of a brown colour, emits brown vapours, has a pungent ſmell, readily diſſolves moſt metals, and is extracted by diſtillation from nitre or ſaltpetre, moiſtened with vitriolic acid. It attacks the phlogiſton of metals, and has the greateſt affinity to it. *Marine acid* is extracted from common ſalt, it is of a yellow colour, and ſmells like ſaffron.

ALKALIES are ſaline bodies that combine readily with acids; in a concrete form they attract moiſture from the air, and become fluid; they have an acid burning taſte; fuſe with a moderate heat; diſſolving earths with a ſtrong heat, become glaſs, &c. *Fixt mineral alkali* is obtained from ſea ſalt; *fixt vegetable alkali* from vegetables, both ſtanding a great heat without diſſipation. *Volatile alkali* is obtained from animal ſubſtances, by decompoſition and putrefaction, and flies off with a *ſmall* degree of heat; hartſhorn drops are of this kind. Alkaline ſalts combined with oils form ſoap, &c.

SALTS are every thing with a ſharp taſte, and ſoluble in water. *Sea ſalt*, or *kitchen ſalt*, is a combination of marine acid and mineral alkali. *Luna cornea* is a ſalt formed by the union of ſilver and acid. *Verdigriſe*, ſalts formed by the ſolution of copper in vinegar. *Ammoniacal ſalts*, are an acid ſaturated with volatile alkali. *Sugar*, an eſſential ſalt, containing vegetable acid combined ed with earth and oil. *Potaſh*, a fixt vegetable alkali extracted from the aſhes of vegetables. *Nitrous ſalts* are found in old walls, or places impregnated with animal and vegetable juices---they are neutral, and produced nitrous acid and fixt vegetable alkali.

METALS. *Perfect metals*, or thoſe that cannot be decompounded, are gold, platina, and ſilver. *Imperfect metals*, are copper, iron, tin, and lead, which in fire, or ſtrong menſtruums loſe their metalline properties, become an earth, or calcs; but are revivable back to their original metals by phlogiſton; hence imperfect metals are wholly compoſed of earthy matters and phlogiſton. Pure metals are always found in their metallic form; but the imperfect metals in the form of calcs's or ores; theſe placed in a ſtrong fire acquire from the combuſtibles phlogiſton enough to become metals, and are then combuſtible themſelves in a ſtrong fire: Sparks produced by the ſtroke of flint and ſteel, are but particles of ſteel ſet on fire by the violence of the ſtroke. *Gold* is unalterable by art, is the heavieſt of all known bodies, expands ſo, that a grain may be beat into a leaf of fifty ſquare inches, and a gold wire one tenth of an inch in diameter, will ſuſpend or ſupport 500lb. weight without breaking. Reduced into fine powder, it is eaſily attacked by acids, but its metallic nature is in no reſpect altered. Gold diſſolved by aqua regia, and then precipitated by volatile alkali, and then waſhed and ſuffered to dry, explodes by a ſmall degree of heat, with a quickneſs and violence far exceeding gunpowder. Ether poured on a ſolution of gold in aqua regia, and the mixture ſhook—the gold will leave the aqua regia and paſs into the ether. Gold will continue months in a hot fire without loſing any weight. *Platina.* This metal is found in ſmall, angular, ſhining grains in the gold mines of South America; it is near as heavy as gold. It diſſolves in aqua regia, but bids defiance to ſimple acids, or any fire, except that of a large burning glaſs. *Silver* is the third unalterable metal—it fuſes in a ſmall heat; is nearly as ductile as gold; a wire of it one tenth of an inch diameter will ſuſtain 270 lb. It aſſumes a black appearance when expoſed to phlogiſtic vapours, for it is capable of over-ſaturating itſelf with the inflammable principle. Nitrous acid diſſolves ſilver more compleatly than any other acid. *Copper*, tho' an imperfect metal, comes near to ſilver in point of ductility. A wire, as above, ſupports 299 lb. Moiſt air tarniſhes, and even calcines it; this ruſt, or calx, is verdigriſe. Acids, alkalies, ſaline matters, and oils, more or leſs diſſolve copper, and the ſolution is of a green colour, and poiſonous, hence culinary veſſels of copper ſhould be kept well tinned. A ſolution of copper in volatile alkali is blue when expoſed to the air, but loſes the colour when corked up; opened, it again becomes blue, &c.—So water impregnated with too little copper to be diſcovered, turns blue with a few drops of volatile alkali. Copper is moſtly found combined with ſulphur in mines; and is eaſily ſeparated from other metals by ſulphur. It requires a ſtrong heat to melt it, emits pernicious fumes, and burns with a green or blue flame. It eaſily combines with other metallic ſubſtances---with zink it becomes *braſs*---with tin, *bronze*, or *bell metal*, &c. *Iron* is the moſt uſeful, the hardeſt, moſt elaſtic, and, except tin, the lighteſt of all metals. Such a wire as above, ſupports 450 lb. As an ore, or a calx, it is not attracted by the magnet---but when phlogiſticated by roaſting in the fire, it is attracted. It is eaſily deprived of phlogiſton, by the calcs of other metals, water, moiſt air, acids, fire, &c. and becomes ruſt, or *crocus martis*. Iron, joined by ſubſtances that abound with phlogiſton, in a ſtrong fire, without the free acceſs of air, becomes *ſteel*; and ſteel made red hot, and ſuddenly cooled in water or oil, becomes ſo hard, tempered, and brittle, that edge-tools, files, &c. are made of it.

In the act of heating it changes colour, and hence many ſteel ornaments are made blue. Iron has great affinity with ſulphur, and its fuſion is ſo much facilitated by it, that if iron in white heat, be rubbed with ſulphur, it falls in liquid drops united with the ſulphur; and if 60lb. of iron filings and ſulphur, made into a paſte with water, be buried a few inches under ground, it will ſwell, grow hot, emit vapours and flame, and ſhake the ground about it like an earth-quake. Iron may be allayed with any metal except quickſilver and lead. *Tin* is the lighteſt, leaſt elaſtic, or ſonorous of any metal. A wire as above, ſupports 50lb. All acids diſſolve and deprive it of its phlogiſton. It melts with leſs heat than will make it red hot, and calcines into a grey powder called putty, (uſed in polliſhing metals, glaſs, &c.) It allays with all metals, gives them brittleneſs; and its vapours impair the ductility of all metals. It amalgamates with quickſilver, and is then uſed to cover looking-glaſſes: compounded with lead it forms the ſolder of the plumbers.---*Lead* is ſtill ſofter than tin; a wire as above only ſuſtains 29lb. Acids of all ſorts diſſolve it—fumes of vinegar ruſt it into *white-lead*. Calcs of lead is made into wafers; boiled in linſeed oil, it becomes the *drying-oil* of the painters. Lead kept in a ſtate of fuſion, with a current of air paſſing over it, ſoon loſes its phlogiſton, and becomes calcined, and is then called *red-lead:* a ſtronger heat vitrifies this calx into *litharge:* and a ſtill ſtronger heat, reduces it into *glaſs of lead*, which will run through the crucible like water through a ſieve. This glaſs facilitates the calcination of imperfect metals, and is therefore uſed to purify the *perfect* metals. *Mercury*, or *quickſilver*, is like fluid ſilver, opaque and very heavy. By great cold it can be made ſolid, and maliable as lead. It riſes in vapour by a ſmall degree of heat, and when theſe vapours are collected, they are found the very ſame quickſilver. Hence it is eaſily diſtilled, and by that means eaſily ſepa-

rated

rated from lead, tin, &c. Acids and alkalies combine with mercury. Vapours of mercury and marine acid meeting, form chryſtals like flattened needles, called *corroſive ſublimate.* Mercury ſhook in vinegar, exhibits a curious phænomenon; and it is luminous when ſhook in vacuo. Quickſilver triturated with ſulphur, forms *Ethiops mineral*; and this frequently ſublimed, becomes cinnabar---or the vermilion of the painters. Cinnabar is alſo found a native in the mines, and may be conſidered as the ore of quickſilver.

EARTHS.

Earths make up the ſolid part of our globe; they are ſo intermixed, that it is difficult to come at their components, which are, 1ſt. *Calcareous earths*, i. e. lime-ſtone, chalk, ſtalactites, or ſtone icicles, marbles, or any earths that effervesce with acids; that fall in white powder when burnt; that will not melt into glaſs by heat; but will melt when mixed with borax, or calcs's, and aſſiſt the fuſion of lead, copper, and iron. *Siliceous earths*, or precious ſtones, as the diamond, ruby, topaz, opal, agate, cornelian, flint, jaſper. Many of theſe ſtrike fire with, and even ſcratch ſteel;—do not melt with the ſtrongeſt fire; and do not effervesce with acids. *Argillaceous earths*, or clays that harden in the fire, and uſed to make porcelain; and clay marles, that moulder in water, and effervesce with acids, uſed as manure. *Micaceous earths* are compoſed of thin leaves, or lamina, with ſhining ſurfaces, and which divide into thinner leaves in the fire, and become brittle. *Aſbeſtus earths.* Theſe do not alter in the fire; are flexible and ſtringy, capable of being ſpun into threads, or wove into cloth. *Zeolites* are harder than calcareous ſtones; melt eaſily in the fire, with ſwelling and ebullition; and diſſolve with acids without efferveſcence.

LECTURE IV.

PNEUMATICS.

THE air is a thin fluid, which encompaſſes the globe of the earth on all ſides, revolves along with it round its axis, and attends it on its annual journey round the ſun. If a peach be ſuppoſed to repreſent the earth, the air will be aptly ſignified by the down growing on its ſurface.

This body of air, together with the clouds and vapours that float in it, are called the atmoſphere; and it reaches about forty-five miles above the ground before it degenerates into too thin an æther for any creature to breathe; this is known by meaſuring with a barometer the weight of the atmoſphere in a low valley, and on a mountain, and may be familiarized by ſuppoſing a thouſand fleeces of wool one piled above another, where the loweſt will be greatly compreſſed or ſqueezed together, the next not ſo much, the next not ſo much as that, &c. till we come to the uppermoſt, which will lie in its natural looſe ſtate. The air, by being elaſtic, and partaking of the earth's attraction, is neceſſarily drawn into a progreſſive ſtate like this.

The air is ſo ſubtil that it pervades the pores of all bodies, and enters into the compoſition of moſt animal and vegetable ſubſtances; yet it is a body, becauſe it excludes all other bodies from the place it poſſeſſes, if ſo confined that it cannot eſcape; hence the origin of the diver's bell, for if we ſink a bell in water with the mouth open downwards, little water will make its way into it, and a perſon may deſcend and live a conſiderable depth, if a veſſel of the ſame kind be kept conſtantly ſupplying him with freſh air, and that made noxious by his breathing be let out by a pipe reaching from the upper part of the bell above the ſurface of the water.

The air has all the properties by which a fluid is diſtinguiſhed, it yields to the ſlighteſt impreſſion, its parts move eaſily among one another, and animals breathe and move through it without any difficulty. Yet it has three ſingularities which diſtinguiſh it from moſt fluids. 1. It can be compreſſed into a leſs ſpace than it naturally poſſeſſes. 2. It can occupy a greater ſpace than it naturally poſſeſſes. 3. It is of different denſity in every part upward.

As the air is a body, it muſt needs have *weight*; this is proved, 1. By its preſſing the hand that covers the top of an exhauſted receiver. 2. By immerſing the ſtem of a bolt-head into a veſſel of water, and covering both with a receiver, then exhauſting the air out of both; on letting in the air on the ſurface of the water it forces it into the exhauſted bolt-head. 3. A bottle that holds a wine quart being emptied of air, and weighed, is found to be about 17 grains lighter than when it is full of air; ſo that a quart of air on the earth's ſurface is 17 grains. 4. If a wet bladder be tied over the top of an open receiver, then ſet to dry, and after this the air exhauſted from under it, the air's weight will then burſt the bladder with a ſurpriſing report. 5. On a moveable plate place a tall receiver, open its cock, and exhauſt the air out of it, then ſhut the cock, and immerſe the ſtem in which it is fixed into a veſſel full of water; on opening the cock the air's preſſure on the water will force it into the receiver in a beautiful fountain. 6. If a hole be made in the bottom of a cup, and have a bit of dry hazel or willow branch fixed into it, and this be put into a hole on the top of a receiver; when quickſilver is poured into it, and the air exhauſted, the quickſilver will be forced thro' the pores of the branch by the weight of the incumbent air, and will fall in a curious ſhower into the receiver. 7. If a tube of 32 inches long, and open only at one end, be filled with quickſilver, and then the open end immerſed in a jar of quickſilver, *that* in the tube will ſink to the height the quickſilver ſtands in the barometer; if this jar and tube be put under a tall receiver, and the air exhauſted, the quickſilver will deſcend out of the tube into the jar; but upon admitting the air again into the receiver, its preſſure will drive up the quickſilver into the tube, and ſupport it therein as is ſtands in the barometer, which proves that the quickſilver in the barometer is kept up ſolely by the weight of the air. 8. If the air be exhauſted out of two braſs hemiſpheres of about 12 inches area, it will require a force equal to 180 pounds to ſeparate them.

To prove that theſe effects are not produced by *ſuction*, and that there is *no ſuch principle in nature*, 1. Place a ſmall receiver at ſome diſtance from the hole in the pump-plate, and cover it with a large one *over* the hole; on exhauſting the air the ſmall one will remain looſe, while the large one is made faſt to the plate; but on letting in the air the big receiver will be releaſed, and the ſmall one preſſed down. 2. If a pump be placed in water under a receiver, and the air exhauſted, no water can be made to riſe in the pump. 3. If two moveable plates be fixed upon a pump-plate, with communications between them that can be ſtopped by cocks, if the air is exhauſted out of a receiver placed on one of them, and then a receiver placed on the other, and the communication opened, half the air in the laſt will by its ſpring make its way into the firſt receiver, and both ſhall be fixed to the plates.

Breathing is in ſome meaſure performed by the power of the intercoſtal muſcles acting upon the ribs; they are diſpoſed in form of a ſemicircular arch, and articulated with the vertebræ of the back behind, and connected with the ſternum before, which are the two centres on which they move: The diaphragma is a partition drawn acroſs the body, dividing the thorax or cheſt from the abdomen or belly; it is a muſcle, and by its diſpoſition and ſtructure capable of expanſion, whereby it becomes concave downward, and of attraction, whereby it becomes flat; and by this motion alternately rarefying and condenſing the air in the crevices of the thorax, and thereby deſtroying its equilibrium; to reſtore this the air will preſs into the lungs, and when the diaphragma contracts, will be forced out again; hence the action of breathing, as is repreſented by the lungs-bladder, whoſe inſide has a communication with the external air, though it is incloſed in a thorax of glaſs with its bottom cloſed by a bladder, tied flaccid, repreſenting the diaphragma.

The *elaſtic quality*, or *ſpring*, of the air is thus proved, 1. If an almoſt empty bladder be put under a receiver, and the air exhauſted, the ſpring of the air in the bladder will then ſhew itſelf by ſwelling up the bladder, as if it was blown. 2. If a little of the ſhell be cut off from the ſmall end of an egg, and the egg put under a receiver, on exhauſting, the bubble of air in the big end of the egg will expand itſelf, and drive out the contents of the egg. 3. If a fiſh in water be put under a receiver, and the air exhauſted, its air-bladder will ſwell the fiſh ſo as to make it ſpecifically lighter than water, and of courſe the fiſh will be buoy'd up to the ſurface. 4. If a cubic inch of dry wood in warm water be put under the receiver, and the air exhauſted, large and innumerable bubbles of air will come out of the wood and make the water ſeem to boil; and in this manner may air be drawn viſibly out of the hardeſt bodies. 5. A withered apple in an exhauſted receiver will be plumped up, and look quite freſh, by the ſpring of the air in the inſide of it; and if a freſh one be pricked all over with a bodkin, and put in water under a receiver, on exhauſting, it will appear as if it was roaſting by a fire. 6. If a tall receiver be exhauſted, and the neck of the veſſel joined to its bottom be half full of water, the ſpring of the air on the ſurface of that water will force it out into the receiver in a beautiful fountain. 7. If a little air be tied up in a bladder, and put in a convenient veſſel with great weights upon it, on exhauſting the air, the ſpring of the air in the bladder will lift the weights, and ſhew that its ſpring is equally forcible with its preſſure; therefore, though a middle-ſized man ſuſtains above 30,000lb. weight on his perſon, yet the equal ſpring of the air within him makes him inſenſible of it.

Heat and cold, or, if you will, the preſence or the abſence of fire, are the uſual cauſes of the air's rarefaction and condenſation: If air be *heated*, it ſwells, ſo that the ſpace it poſſeſſed before it was heated will contain fewer particles than it did in its cold ſtate. *Wind* muſt be the neceſſary conſequence of this; for by what means ſoever the equilibrium of the air is deſtroyed, its neighbouring parts will never be at reſt till the balance is reſtored: Hence the reaſon why air ruſhes ſo violently into a glaſs-houſe; into a cloſe room with a great fire in it; into warm towns, &c. When the ſun's heat is increaſed by the reflection of ſands, or the ſides of rocky mountains, &c. the air will be rarefied, and by the ruſhing in of the colder neighbouring air, will be forced up into the higher part of the atmoſphere, as light ſmoke is up a chimney by the heavier air. If a large cloud keeps the ſun's rays from the *air* under it, but rarefies *that* all round it, a wind will ruſh from beneath the cloud in all directions. Upon this principle alſo we account for the *trade winds* which conſtantly blow from the eaſt to the weſt about the equator; for as the ſun paſſes over the earth in that direction, and rarefies the air as he goes, the colder air will ruſh after him and cauſe the *trade winds*, if they are not diverted by *vulcanos*, *burning ſands*, *mountains*, *&c.* Hence alſo the *monſoons*; the *day* and *night* breeze, on the iſlands in the Weſt-Indies; the wind from weſt to eaſt on the coaſt of Guinea; and the currents of Florida, Gibraltar, *&c.*

'Tis unneceſſary to point out here how admirably theſe properties coincide with the general ſcheme of the creation.

LECTURE V.

PNEUMATICS.

THAT the air may be condenſed or ſqueezed into leſs room than it naturally poſſeſſes is proved, 1. By putting a blown bladder in a receiver; if a forcing ſyringe be then applied to the receiver, and a quantity of air forced into it, the bladder will be ſhrivel'd up by the ſuperior preſſure of the condenſed air. 2. If a copper ball be half filled with water, and a quantity of air forced into it as above, through a ſpouting pipe that goes near the bottom of the water, the ſpring of the condenſed air on the ſurface of the water will exhibit an amazing fountain. 3. The moſt formidable inſtance of condenſion is in the magazine, and walking-cane wind-guns; where the condenſed air has a ſpring capable of diſcharging 20 or 30 balls with one charge, one after another, with the ſame force as if charged with gunpowder.

By compounding certain bodies, an aſtoniſhing quantity of air will become fixt or concreted in the pores of the new body; of this kind are the grains of gunpowder, to which if fire be applied, the air will inſtantly re-aſſume its elaſtic form, and its ſudden ſwell being reſiſted by the adjoining air, will cauſe an exploſion: For this reaſon gunpowder fired in vacuo makes no exploſion.

Sound is cauſed by any thing that gives a ſmart ſtroke or a tremulous motion to the air; theſe waves ſtriking upon the outward ſhell of the ear, are from thence conveyed up the auditory tube, and ſtriking againſt the tympanum, or drum, are ſo increaſed, that in making their way up the labyrinth, it gives a ſhock to the auditory nerves, and, by their means, is conveyed to the ſoul the idea of hearing, or ſound. The artificial ear makes this very evident. And the clock ſtriking in vacuo without being heard, is a proof of air being a conductor of ſound. Muſical ſtrings, in tenſion, ſtruck by a bow, a finger, the wind, &c. will divide themſelves into imaginary frets, or bridges, viz. into halves, thirds, fourths, &c a bridge, either real or imaginary, dividing a ſtring into *two* equal lengths, each *(vibrating according to their weight)* will be an *octave* to the whole ſtring, as half will vibrate twice as faſt as the whole; and hence every ſecond wave unites with the firſt of the whole ſtring, and gives a pleaſing ſenſation to the ear.—A ſtring divided into *three equal parts*, each will vibrate three times while the whole ſtring vibrates once; hence every third wave coming in contact produces a pleaſing ſenſation, and the chord is called a *Twelfth*. Two thirds of this ſtring vibrates *three times*

while

while the whole ſtring vibrates *twice*, and gives that ſweet chord called a *Fifth*. *Seven ninths* of a ſtring produce the major *Third:* and *three fourths* the *Fourth*. Hence waves claſhing againſt one another without contact, produce *diſchords* in muſic, and ſerve as foils or reliefs to the counterpoint of according waves. Hence alſo the mechanical ſympathy of muſical inſtruments tuned in uniſon; one of which will ſound when the other does, by the waves it produces. An harpſichord replies to every word ſpoken in the room where it ſtands. Particular notes in an organ will ſhake the wainſcot, ſet dogs a howling. Hence alſo the various ſounds produced by the Eolian harp, when tuned uniſon, and expoſed to a current of wind—the ſtrings divide themſelves into imaginary bridges, and produce *octaves*, *fifths*, *thirds*, *twelfths*, *fifteenths*, &c. The maſterly performer on the violin aſſiſts this propenſity, by touching lightly thoſe aliquot parts of a ſtring where nature would make this imaginary bridge, and hence are produced thoſe notes called *harmonics*.

When the atmoſphere is light, the noxious air pent up in the cavities of mines (communicating with the outward air) will, by its effort to reſtore an equilibrium, ſwell into the mine, and hence the ſuffocating damp which is met with in mines when the barometer is low. This damp is made on the air-pump by letting air into an exhauſted receiver, through the flame of charcoal, ſulphur, flame of a candle, &c. into which if an animal be put it ſuffers inſtant death. The fire-damp proceeds from the ſame cauſe, only that its particles are of the phlogiſtic or inflammable nature, as riſing from the ſulphurous, nitrous, or oleaginous ſtrata in the mine: This, taking fire by the lights uſed by the workmen, will run like a train of gunpowder through the works; and as it is confined, the elaſticity occaſioned by the heat will cauſe ſuch exploſions as frequently blow up the mine. This damp is made on the pump, by letting the air into an exhauſted receiver through the flame of the oil of turpentine or other inflammable matters; after which, if a lighted candle be put in the vapour, it will take fire.

As the pores and cavities of all bodies are filled with air, an animal put under a receiver, and the air exhauſted, will ſoon die; becauſe as the air is drawn out of the lungs, *that* in the thorax will expand and ſwell the animal, ſhrivel up its lungs, and thereby ſtop the circulation of the blood.

Fixed air (that wonderous antiſeptic) ariſes from the effervеſcence of any acid and alkaline mixture, and eaſieſt from chalk and oil of vitriol.—Liquors fermenting diſcharges plenty of it, and it is found alſo in the common atmoſphere. Water imbibes it, and thence acquires the ſparkling appearance, acidulous taſte, and medical qualities of *Pyrmont water*. Though noxious when breathed, it cures the ſea ſcurvy, putrid inteſtines, inflamed, or putrid ſores, &c.

Nitrous air is produced from the effervеſcence of copper filings and the nitrous acid.—It diminiſhes common air, and their mixture gives a brown effervеſcence.

Inflammable air, the pure and elementary phlogiſton, is eaſieſt procured from iron filings and diluted vitriolic acid; the acid ſeizes the iron, and lets looſe the fixt phlogiſton, exhibiting it as *elaſtic air*. This *gas* is imbibed by any metallic calx, in a ſtrong heat, and the calx becomes revived into its original metal. Lead in calcining loſes its phlogiſton—and becomes a calx called minum or red lead:—This phlogiſton preſerved, if the calx be placed in it, and the focus of a burning lens heat the calx, it inſtantly begins to imbibe the inflammable air, ſwallows it up, and ſoon becomes the individual lead it was before the proceſs. This is taking a metal in pieces, and putting it together again; and intimates the *inflammable principle to be the ſame in all bodies*, viz. that inflammation in coals, candles, wood, &c. ariſes from letting looſe concreted phlogiſton from theſe ſubſtances into the air.—*Inflammable air* being eight or ten times lighter than common air, riſes from bogs, and putrifying ſubſtances into the higher regions of the atmoſphere, and lodging there, frequently receiving inflammation from lightning, or electricity, giving *thunder* its long progreſſive ſound---*Lightning* the property of ſpreading over the whole hemiſphere---and when by winds it is drawn into long ſtreaks acroſs the hemiſphere, and receives from electricity inflammation at one end, the inflammation runs acroſs the hemiſphere, and we call the phænomenon *falling ſtars*, *fiery dragons*, *meteors*, *Will-o'th'-wiſp*, &c. ---A ſoap bubble, filled with inflammable air, riſes in the atmoſphere like a ſhot diſcharged from a perpendicular gun. *Inflammable air*, when mixt with an equal quantity of common air, or a third of dephlogiſticated air, explodes when confined in a gun, and inflamed by electricity, ſo as to diſcharge a ball with a force nearly equal to gunpowder.

Copper and ſpirit of ſalt produce an air (through quickſilver) that is very noxious,---quickly abſorbed by water, ---and a candle burns green in it. Water ſaturated with it is a ſtrong ſpirit of ſalt, and diſſolves iron with great rapidity.

Alkaline air is expelled by a candle from a gun-barrel filled with one-fourth pounded ſal amoniac, and three-fourths quick lime mixed.

Common air imbibes *phlogiſton*, which diminiſhes *that* air by precipitating the fixed air it naturally contains; and it becomes noxious in proportion to the diminution it is capable of ſuffering. —Hence phlogiſton is the beſt teſt of air---unwholeſome as it has more in it, and incapable of diminution; and wholeſome as it has leſs phlogiſton in it. For air imbibing this inflammable matter from the blood in its paſſage through the lungs, performs the office beſt when it has the leaſt phlogiſton in it. Hence candles go out in cloſe rooms, and animals die in them; becauſe air already ſaturated with phlogiſton can contain no more.

Vitriolic acid air is produced by oil of vitriol juſt covered with olive oil in a vial, and diſcharged by a candle through quickſilver. Ice inſtantly melts in this air; and alkaline air put to it produces a white flaky precipitation.

Fluor acid air is forced by a candle from a vial containing pounded ſpar and oil of vitriol, through quickſilver into water. The phlogiſton in the ſpar gives volatility to the vitriolic acid, ſo that, coming into contact with the water, they unite, and the ſtony matter of the ſpar precipitates in flakes, cruſts, &c.

Dephlogiſticated air, (or perfect atmoſpheric air) ſeems to be derived from earth and the nitrous acid, and bids fair to rob us of a received element. It is expelled by a ſmart fire from a paſte formed of red lead and ſpirit of nitre, out of a gun-barrel or a thin vial---or any earthy matter void of phlogiſton, as pipe-clay, &c. In a given quantity of this remarkable air an animal will live near ſix times as long as in the ſame quantity of common air! A candle burns with an aſtoniſhing brightneſs in it,---a firebrand crackles in it,---and inflammable air explodes prodigiouſly loud in it, &c.

All ſubſtances, vegetable, animal, or mineral, mixt with nitrous acid, and expoſed to a proper heat, give dephlogiſticated air---if the ſubſtances be firſt deprived of phlogiſton. But if the ſubſtances contain much phlogiſton, (in thoſe circumſtances) they give *nitrous air*. If but a ſmall quantity of phlogiſton, *fixt air*; but if no phlogiſton, the produce is *dephlogiſticated* air.---So when a ſmall quantitity of phlogiſton exiſts in the ſubſtance uſed, the *fixt* and *dephlogiſticated airs* generally come over together.

From the ſmoke---putrid effluvia---calcination of metals---and breathing of animals, the air muſt be continually contaminated, and made unfit for human reſpiration. Providence has wiſely made the vegetable kingdom the cure for this evil, for plants imbibe nouriſhment from putrid and phlogiſtic air at their leaves, as may be ſeen by the ſuperior vigour in plants growing in great cities---by their growing on walls without earth---and by a green plant put in noxious air, which imbibes nouriſhment, and cures the air at the ſame time. The air ſo purified in leaves and plants, leaves them, and becomes dephlogiſticated, if the leaves and plants be expoſed in water in a tall inverted glaſs, and expoſed to the light.

Reſpiration is alſo a phlogiſtic proceſs, affecting air in the very ſame manner as putrefaction, efferveſcence of iron filings and ſulphur---calcination of metals, &c.---diminiſhing its quantity and ſpecific gravity, and rendering it unfit for reſpiration and inflammation---yet ſtill capable of being reſtored by agitation in water, or a contact with vegetables. Air comes nearly in contact with the blood in its paſſage through the lungs, giving phlogiſton to it when it wants, and taking phlogiſton from it when it has too much. Too much phlogiſton renders the blood black and thick—but the air having acceſs to it, even through the veſicles of the lungs, renders it red again—and *dephlogiſticated air ſtill more perfectly* ſo, both in and out of the body---congealed as well as fluid, &c.

That *water* is preſent in *air*, is evident from ſeeing it precipitate in a cloud as a receiver is exhauſting on the air-pump; from the *dew* on windows, or other cold bodies when water ſtands for ſome time in a hot room; from the wet hair of thoſe who aſcend the ſides of mountains; and from its entering ſpunges and hygrometrical inſtruments when hung in air; from many more proofs 'tis evident that *air is a menſtruum for water*. *Air*, lying on *water*, and rubbing perpetually againſt it, from this contact, and their natural attraction, the two fluids mutually imbibe one another; (for air may be ſeen in water placed in an exhauſted receiver.) That an *heavy* body can riſe in a lighter one when its particles are ſeparated, and its ſurface by that means increaſed, is certain from *gold* being diſſolved, and of courſe hanging, in *aqua regia*, ---*copper* in *aqua fortis*, *&c.* *Water* riſes in *air* by the ſame law; and the ferment occaſioned by all ſolutions may be ſeen in the air along the ſurface of wet ground, on a warm day, in that *quivering* which the rays of the ſun ſuffer in paſſing through air and water not yet *intimately mixed*. *Heat aſſiſts all ſolutions*, --- hence the quantity of clouds and rain where the ſun is vertical: --- The drying quality of the air in ſpring, and the rains and fogs in winter; for ſummer's warmth aſſiſts in filling the air with water, and the winter's cold condenſes and brings it down in high latitudes; and as the higher regions of the air are cold, and thin, the particles of water run together, and form *clouds*, about the height of the mountains: --- The winds, and their own attraction, aſſiſt this junction --- till their ſurface becomes ſo diminiſhed that they precipitate in a *drop of rain:* If the drop is frozen in its deſcent, it falls on the ground an *hail-ſtone:* If the *cloud* be frozen, then broken fragments of it deſcend in *flakes of ſnow. Fogs in an evening* are occaſioned by the cold condenſing the vapours new raiſed from the ground before they are properly mixed with the air.

LECTURE VI.

HYDROSTATICS.

THIS branch of philoſophy treats of the *nature, gravity, preſſure, and motion of fluids* in general, and of weighing ſolids in them. *Water*, like *air*, conſiſts of *round* and *hard* particles, as is proved by putting ſalt in water without increaſing its *bulk*, by the *round* pores of aquatic plants and the *Florentine experiment*, which forces water thro' the pores of a copper ball: Hence 'tis evident *there are vacuities in fluids*, and that no fluid can be preſſed into a *leſs ſpace* than it naturally poſſeſſes, except *air* and *ſteam*.

Fluids are ſaid to be *perfect* or *imperfect*, as their parts ſlide with more or leſs eaſe over one another, therefore quickſilver is the moſt perfect of all fluids. Water being of the *imperfect* kind is ſeldom *pure:* It adheres to any ſubſtance it meets with, mixes with its particles, and thence becomes impregnated with whatever *ſtrata* it runs over: If water has any thing alkaline in it, the *ſyrup of violets* turns it *green*; if any thing acid, the *ſyrup* turns it *red*; if it has run over *iron ſtone*, or *iron mine*, a ſolution of *galls* turns it *black*, and if allum, *oil of tartar* turns it *thick*, &c.—Hence water impregnated with lime-ſtone, and ouſing ſlow amongſt moſſes, leaves, &c.—as the water evaporates, the ſtony matter adheres to theſe ſubſtances, and aſſuming their ſhapes, gives that variety of whimſical petrefactions we meet with in Derbyſhire,—the dropping well at Knareſbrough, &c.

Water being *incompreſſible* will not be more *denſe* at the *bottom* than the *top* of the ſea; but will have the wonderful property of preſſing, *upwards* and *ſideways*, as forcibly as *downwards*, in proportion to its *perpendicular height*, without any regard to its *quantity*; for as each particle is quite free to move towards that part on which the preſſure is *leaſt*; and hence no particle or quantity of a fluid can be at reſt till it is *every way equally preſſed*. A fluid may therefore be conceived as made up of *perpendicular columns of particles*, and as divided into *imaginary ſurfaces* each an inch or more from one another, the loweſt preſſed with the weight of *all* the reſt, *&c.* hence the pipe fixed under the *moſt* ſurfaces will diſcharge the *moſt* water, *&c.*

To prove that fluids preſs in all manner of directions alike, take four *glaſs tubes*, open at both ends, but bent into all kinds of angles; if theſe be put in water nearly to their tops, the water will riſe in them to its own level. Or take a veſſel full of water, with an hole at the *bottom of its ſide*, of the ſame ſize as one in its *bottom*, and the two holes will be found to diſcharge the ſame quantity of the fluid in the ſame time.

That fluids preſs in proportion to their depth, without any regard to their quantity, is evident, 1. From a *bladder* tied flaccid over one end of an open *cylinder of glaſs*; if water be poured into it, the bladder will bulge *downwards*; but if then it be immerſed in a veſſel of water till the ſurface of the water within the cylinder be *even* with that in the veſſel, the bladder will then be *flattiſh* as if it were not preſſed at all, for indeed it is then preſſed equally. If the cylinder be plunged *deeper*, the bladder will be preſſed *upwards*, ſhewing that bodies ſwim merely by the force of the pillar of water under them endeavouring to riſe to its level. 2. *Lead* is about 11⅓ times heavier than its bulk of water; if therefore a piece be held tight to the mouth of a cylinder, (open at both ends) by a ſtring within the cylinder, and let down into water above 11 times its thickneſs, the ſtring may be let go, and the upward preſſure of the water will hold the lead to the cylinder; but if the cylinder and the lead be raiſed till the lead is not 11⅓ times its thickneſs below the ſurface of the water, it will then fall off and ſink. 3. If a tube of 34 inches, open at one end, and filled with quickſilver, have its open end immerſed in a baſon of quickſilver, hung ſo by ſtrings that it may be *let down* into a deep veſſel of water, according to the depth the veſſel is *ſunk*, the mercury will *riſe a fourteenth part* in the tube, and demonſtrate that quickſilver is fourteen times heavier than water. 4. If lead with a *flat upper ſide* be laid on the bottom of a veſſel, and a piece of *flat* wood be held on while the veſſel is filling with water; if no water can get in between the lead and the wood to form an *upward preſſure*, the wood will be held on the lead by its own weight and that of the water above it. 5. If an *empty bottle*, juſt made ſo heavy as to ſink in water, be corked, and ſuſpended at one end of a balance, and, with its cork pulled out, be immerſed in water and filled, it will require as *much weight* in the oppoſite ſcale to pull it up, as will weigh all the water in it, which ſhews that fluids weigh juſt as much in their *own* element as out of it. 6. If a ſmall tube 30 inches long, open at both ends, and to one end (bent to a right angle) it has a *large bladder* tied; if then the bladder be put in a box, and a board be laid on it with 25 or 30lb. weight upon it, and water be poured into the tube, the bladder will raiſe the weights, though the bore of the tube ſhould be ſo ſmall as not to hold an ounce of water. 7. *The preſſure of a fluid upon the bottoms of all veſſels whatever, is proportional to their baſes and perpendicular height, without any regard to the quantities they contain*; for if on a looſe piſton, ſuſpended on a balance, a column of water of a foot be weighed, it will be found to weigh as much as a column of water of the ſame height, though contained in a flanging veſſel that holds ten times as much. 8. If a *ſmall tube* be joined to a *very large one*, and the whole be bent in the bottom ſo as the two parts may be either *parallel*, or make *any angle*, water may be poured into *either tube*, and it will juſt riſe as high in the *other*, even tho' one ſhould contain ten thouſand times as much as the other does: This alſo ſhews that fluids preſs in proportion to their perpendicular heights, without any regard to their quantities; that water in pipes will aſcend to the *level of the ſpring* from whence it came; and that *jets* or *fountains* would riſe the *ſame height*, if not obſtructed by *angular turnings*, and the *reſiſtance of the air* into which they play.

Smoke does not riſe into air becauſe of its *poſitive levity*, but becauſe it is *lighter* than the air where it is produced; hence if the ſmall neck of a bolthead, full of water, be immerſed in a glaſs of wine, the *lighter wine* will aſcend up into the bolthead, and the *heavier water* deſcend into the glaſs. For the ſame reaſon, a body ſpecifically (or bulk for bulk) *heavier* than water will ſink in it; a body of the *ſame weight* will lie indifferently any where in it; and one ſpecifically *lighter* will of courſe ſwim in it.

Smoke is forced up a chimney by the air in the room, preſſing to the rarefied air *in* the chimney; --- hence, the patent ſtoves, contracting the fire-place, obliges the air to ruſh *in* with great violence, and thereby it overcomes

comes more effectually any wind that forces the ſmoke *down* the chimney.---Kitchen, or other open chimnies, are very liable to ſmoke with winds coming *over*, or boſoming *againſt* a taller houſe, church, tree, &c.---becauſe the ſmoke riſing very ſlow and languidly by its ſpecific lightneſs in the open air, or wide chimnies, is eaſily puffed down by the wind, if a ventilator or a feathered covering do not prevent it.

If a ſtick be counterpoiſed on a ſcale-beam by water, and after that immerſed in a veſſel full of water, it will cauſe ſo much of the water to flow over the brim as will be ſupplied by *that* in the oppoſite ſcale: Hence it is evident a *ſhip* diſplaces juſt ſo much water in the ſea as is equal to its own weight and cargo: And hence alſo the *ſtrength of wood* may be judged of; for if a piece of oak of a foot long be immerſed in a narrow veſſel of water, it will be found to ſink about eight-tenths of its length: Beech about ſeven-tenths: Mahogany ſeven-tenths, &c.

A ſolid body, heavier than its bulk in water, will loſe juſt ſo much of its weight when ſuſpended in it, as its bulk of water weighs: But the weight loſt by the ſolid is communicated to the fluid. Hence if the weight of a body in air be divided by what it loſes in a fluid, the quotient will ſhew how much heavier it is than its bulk of that fluid, or its *ſpecific gravity*. By this trial, *pure gold* is found to be 19,637 times as heavy as its bulk of water: *Guinea gold* 17,793 times as heavy: *Quickſilver* 14 times: *Lead* 11,325 times: *Standard ſilver* 10,535: *Copper* 9: *Plate braſs* 8: *Steel* 785: *Iron* 7,645: and *block-tin* 732. A cubic inch of braſs loſes $233\frac{1}{3}$ grains of its aërial weight in water: In proof ſpirits it loſes 235 grains; therefore a cubic inch of water weighs $233\frac{1}{3}$; and a cubic inch proof ſpirits 235 grains: And the ſpecific gravities of *pure ſpirits*, *proof ſpirits*, and *water* are as

840,923

840,923 and 1000. From hence may be conceived the great uſe of the hydroſtatic balance.

A *pipe* fixed *four times* as deep below the ſurface of a fluid as another of the ſame diameter, will diſcharge *twice* as much in the ſame time; if *nine times* as deep, it will diſcharge *four times* as much, &c. agreeable to the ſquare root of the depth: And the *velocity* with which a fluid ſpouts at any depth below the ſurface, is equal to that which a body let fall *that height* would acquire. Pipes alſo diſcharge a fluid (when placed at equal depths below the ſurface) agreeable to the ſquares of their diameters, i. e. a pipe *twice* the diameter of another will diſcharge *four times* as much of the fluid, in the ſame time; *thrice* the diameter, *nine times* as much; four times the diameter, *ſixteen times* as much, &c.

The preſſure of water againſt banks, the ſides of containing veſſels, &c. is in the proportion of falling bodies, viz. if the preſſure againſt the firſt inch deep of the veſſel be one pound, it will be three pounds preſſure upon the inch below that; five pounds againſt the inch below that; ſeven pounds againſt the inch below, &c. ſo that preſſure againſt banks, flood-gates, &c. is as the ſquare of the depth, i. e. if the preſſure be 1 pound againſt the uppermoſt inch, it will be 4 pounds againſt two inches deep, 9 pounds againſt three inches deep, 16 pounds againſt four inches deep, 25 pounds againſt five inches deep, &c.

Fluids *preſs*, or *reſiſt*, according to their *denſity*; and hence a boat will carry more on *ſalt* than *freſh* water. *The hydrometer* ſhews *this* very perfectly; it is buoyed up by *ſalt and water* mixed with *vinegar*, &c. but ſinks in *wine*, *ſpirits*, &c. according to their lightneſs, and hence it is uſed for trying the lightneſs or ſtrength of liquors.

A *ſyphon* acts agreeably to that *equal ſtate* which nature affects through all her operations; it will not run unleſs the height of water in the *outer* leg be greater than that of the *inner* leg above the water in which it is immerſed; as the water falls therefore from the *outer* leg, it will make a continued *vacuum*, and of courſe the *preſſure of the atmoſphere* on the ſurface of the water will force it through the ſyphon in a *continued ſtream*, if kept free from that lodgment of air which frequently takes place on the top of the ſyphon. By the *Tantalus cup*, and *fountain at command*, the cauſe of *intermitting ſprings* is explained thus:

Clouds, being attracted by the mountains, give a continued ſupply to thoſe reſervoirs of water which are frequently found in the bowels of mountains, and which ſupply *ſprings* in general: But ſhould the channel from one of theſe reſervoirs be formed like a *ſyphon*, of courſe the ſpring which proceeds from it will *ebb* and *flow* like thoſe in Derbyſhire, Berkſhire, &c.

The action of the *common pump* depends on the *preſſure of the atmoſphere*: When the piſton is drawn above what is called the ſucking-valve, it cauſes a vacuum, and the water will be forced up 33 feet, but not higher; which ſhews that a column of water of *that* height is equal to the weight of a column of air, of the ſame thickneſs, reaching from the earth's ſurface to the top of the atmoſphere. Therefore at any diſtance above the ſurface of the well leſs than 33 feet the piſton will work, and water from thence may be lifted to any height whatever, if the pump be ſtrong enough. In a *forcing pump*, the piſton is *a ſolid plunger*; it raiſes the water above the ſucking-valve as in the laſt, but when the plunger deſcends (as the water cannot return through the valve back again) it forces it into a larger air veſſel which communicates with the body of the pump above the ſucking-valve; and as by this force the air in the veſſel becomes condenſed, its re-action on the water cauſes it to flow through a ſmall pipe in a continued ſtream. The engine for extinguiſhing fires conſiſts of two ſuch forcing pumps, with their air veſſels.

The *lifting pump* can only be uſed in deep water, as its piſton is worked by a rod going in at its bottom, and faſtened to a frame coming up each ſide of the pump: This piſton has a valve opening upward, and it works below the ſurface of the water in which the pump is immerſed, and thence has no occaſion for the air's preſſure, or a ſucking-valve. This pump is generally equipt with an air veſſel as the laſt. On theſe principles engines are made for raiſing water above the level of rivers or ſprings; but if three pumps are worked in any engine by a triple crank, and all of them throw their water into one pipe, there is no occaſion for an air veſſel, becauſe there will be always one or other of the piſtons acting, ſo as to force the water out in a regular ſtream.

Archimedes's ſcrew pump raiſes water by its endeavour to fall—'tis three or four hollow threads of a ſcrew wound round a ſolid cylinder; it muſt riſe out of the water ſloping, ſo as the threads may all incline downwards; then, when 'tis turned round, water will riſe in it, but to no great height.

The *upright cylindrical mill*, by Dr. Barker, is a tall tube of wood or metal, 20 feet high, and about five inches diameter; it ſtands on a point perpendicular; and has to its bottom two or more horizontal arms, or tubes, fixed, of about ſix feet long, communicating with the upright tube, and perforated with holes, one in each arm, and on the ſame ſide in each; through theſe holes the water which flows in at top ſpouts out, and by giving a puſh to the air, and preventing the water's preſſure on that ſide the arm, forces the whole machine round, and carries a pair of ſtones at top, or pumps, or any thing elſe capable of being moved by a circular motion.

The *bucket engine*, for raiſing water by pumps out of mines, &c. is well calculated for ſituations where the ſtream that carries it has three yards of fall, and is too ſmall to carry a wheel: The bucket hangs on one end of a beam like that of a fire engine; and at half the diſtance from thence to the fulcrum hangs the pump rods; on the other end of the beam hangs a counterpoiſe, rather heavier than the empty bucket, and a column of water on the piſton; but when the bucket is filled by the ſtream, *it* is heavier and deſcends; the bucket hangs on centres a little on one ſide its centre of gravity, ſo that one ſide is heavier when empty, and the other when full, and being unlocked by its deſcent, its unequal poiſe turns and empties it, and then it aſcends and opens a valve which again lets the ſtream into it, and makes it deſcend again. This motion works the pumps.

Two forcing pumps, for ſupplying houſes with water, are alſo worked by an engine of ſimilar principles, but with ſtill greater ſimplicity: A beam inclining downwards to each end from the centre on which it hangs, has a trough cut in it, from a diviſion in the middle down to each end, where buckets are fixed for receiving the water that works it, and which flows into the trough, firſt on one ſide the diviſion and then on the other, as the ends riſe and fall: When one bucket deſcends, the valve in its bottom falls on a pin, which opens it, and lets out the water; mean while the ſtream is filling the other bucket, which, when full, deſcends in like manner, and each end works a forcing pump.

The *centrifugal machine* claims ſtill greater merit in force and ſimplicity; its ſhape it like the letter T, 'tis hollow throughout, and its three ends are open: When the loweſt end is immerſed in water, and it is whirled round on that end, the air in the arms will be partly thrown out by the centrifugal force, and conſequently the preſſure of the atmoſphere on the ſurface of the water into which it is immerſed will force it up the tube and throw it out at the arms; hence a continued vacuum is made, and of courſe a continued ſtream forced out. The perpendicular tube muſt not be above 33 feet high, for reaſons already given. Two men will diſcharge near three times as much water with this machine, in the ſame time, as with any pump yet invented.

The *fire* (or rather *ſteam) engine* is one of the nobleſt preſents that art has made to the neceſſities of mankind! When the particles of *water* are ſeparated by *fire*, they compoſe an *elaſtic vapour*, called *ſteam*; this vapour is capable of occupying 14,000 times the *ſpace* it did in its ſtate of *cold water*; 'tis of force ſufficient to drive away the air, and it may be condenſed, or brought back to water again by *cold*. Hence a long hollow *cylinder* of iron communicates with a huge and cloſe *boiler*, half filled with water, by a neck which can be opened or ſhut by a ſliding valve called a *regulator:* The *cylinder* is exactly filled by a *piſton* made *air-tight*, that hangs on one end of a *beam* of timber about 20 feet long, and ſuſpended on a centre like a ſcale-beam; at the other end of the beam hang the *rods* which work the *pumps* in the bottom of the *mine*, and throw up a part of the water into a *reſervoir* on the top of the building: From this *reſervoir* there comes a *pipe* under and through the bottom of the *cylinder*, that by opening the cock (called the *injection cock)* plays a *jet* of cold water into the *cylinder* to condenſe the ſteam; after which this water falls through a pipe (with a valve opening outward) and forms the *hot-well:* Another pipe alſo, with a valve outward, called the *ſnifting valve*, is fixed near the bottom of the cylinder, and ſerves to let out the *air* or *ſteam* without letting it return. The *regulator* or *injection cock* are alternately opened and ſhut by a piece of timber hanging from the large beam; and a ſtream is let into the *boiler*, or ſtopped, by a floating *copper ball* in the boiler that regulates the height of the water. If now a *large fire* be put under the boiler, and the ſteam let into the cylinder by opening the regulator, it will drive out the air, and poſſeſs the ſpace itſelf; but ſo ſoon as the *injection cock* is opened, a *jet of cold water* will play into the ſteam in the cylinder, and *condenſe* it into a *few drops*; hence a *vacuum* is formed in the cylinder, and the *preſſure of the atmoſphere* on the *piſton* will force it down to the bottom of it; the ſteam then being let in again will counteract the air's preſſure, and with the weight of the pump rods on the oppoſite end of the beam, bring up the piſton to the *top* of the cylinder. This action is repeated *fourteen* or *ſixteen* times in a minute, and works the pump in the mine. As the *friction* of this machine is very great, inſtead of reckoning 15 lb. preſſure on every ſquare inch on the piſton, 8 lb. will be found nearer. If then the weight of a column of water, the depth of the mine, and the diameter of the pump be calculated, the neceſſary diameter of the cylinder will be eaſily found.

The *fire engine with the inverted piſton* ſpares the expence of both a *beam* and *building*; the cylinder, with its open end downwards, ſtands over the pit or ſhaft of the mine, the boiler ſtands by its ſide, the *injection well* above it, and to its *piſton* the *pump rods* are faſtened. The *regulator* (of great ſimplicity) is the *injectiou cock* alſo. When the ſteam is let in at the top of the cylinder, and condenſed by the injection water, the *upward* preſſure of the atmoſphere forces the piſton from the bottom to the top of the cylinder, and the weight of the rods, and ſtrength of the ſteam forces it back again. This motion works the pumps.

The *cold water vacuum* will do this buſineſs with ſtill leſs *machinery* and *expence*, where the water that works it has a fall of 40 feet. With the bottom of the cylinder there communicates a perpendicular wide pipe of 33 feet long, having a regulator at its bottom, and another at its top. The piſton and beam are the ſame as in the common *fire engine.* The water being let in at the bottom of the cylinder will fill both the cylinder and the pipe below it; if then the regulator at the bottom be opened, the water will deſcend out of the *cylinder*, but not out of the *pipe*, becauſe it is *then* but a *counterpoiſe for the atmoſphere:* Thus a *vacuum* is formed in the cylinder, and the piſton will *deſcend* and ſhut the upper regulator; but when it reaches the bottom, it opens again, and as the cylinder fills, the piſton riſes. Thus action is given to the beam; and *water* applied in this way is perhaps a more *powerful agent* than it is in any other.—N. B. *For ought I know, theſe two engines are new, and unknown to the public.*

Watts and Boulton's ſteam engine condenſes the ſteam, without cooling the cylinder by a jet of cold water, and thereby ſaves fuel. The ſteam is produced in a boiler as uſual—it paſſes into a double cylinder, and forces down the piſton by its elaſticity, for the rod of the cylinder works through a collar of leathers, and therefore the preſſure of the atmoſphere has nothing to do in this engine. When the piſton is at the bottom of the cylinder, the ſteam-cock opens, and by the double cylinder, ſteam enters both above and below the piſton, ſo that it riſes in ſtagnate ſteam by the weight of the pump rods acting on the oppoſite end of the large beam. When the piſton arrives at the top of the cylinder, a cock opens that communicates with a vacuum formed in a pond of cold water; this draws the ſteam from *under* the piſton in a moſt perfect manner, and leaves the piſton liable to the preſſure of the ſteam *upon its top*: and as ſteam may be made of much ſtronger preſſure than the atmoſphere, this engine is proportionably more powerful than the common engine.

LECTURE VII.

ELECTRICITY.

ELECTRICITY and *phlogiſton*, having many properties alike, many think them only modifications of the ſame principle. Iron loſing its phlogiſton by vitriolic acid, loſes by the ſame proceſs its electricity; proved by inſulating the proceſs, when a wire communicating with the efferveſcing mixture, will betray ſigns of negative electricity. This moſt ſubtil fluid, ſeems more or leſs inherent in all matter—but ſome bodies conduct or tranſmit it, whilſt others ſtop its progreſs from one body to another. Glaſs, hair, ſilk, and gums are *non-conductors*, and called *electrics*: but metals, water, green wood, and moſt animal and vegetable ſubſtances are *conductors*, and are called *non-electrics*. 1. If a long tube of glaſs be rubbed with a warm flannel, an atmoſphere of this fire will be formed all round it, and if a finger approaches the tube, the fire will come viſibly off the tube into the finger with a ſnap: The reaſon is, the friction collects the fire, and the ſpark is the effort it makes to diſperſe itſelf again, and thereby reſtore its equilibrium. 2. If the ſame tube electrified, approaches a *feather* hung by a ſilk thread, it will *attract* the feather once, but if held to it again, will *repel* it. The ſilk will not conduct the electric fire; the equilibrium is therefore effected between the tube and the feather on the firſt approach; on the ſecond, the atmoſphere of the tube preſſing on that of the feather, drives the feather from it, (for two bodies poſleſsed of the ſame electricity univerſally repel one another;) but if the feather be ſuſpended by a flaxen thread, the electrified tube will always attract it, becauſe the fire can make its eſcape up the thread, and thereby leave a continued inequality between them. A *large globe* or *cylinder* of glaſs, with a *baſil-ſkin cuſhion* covered with an amalgama of quickſilver and tinfoil, or zinc, or aurum moſaicum ſpread on black ſilk, ſaturated with mercurial ointment, to produce the friction; a *prime conductor* to take off the *electric atmoſphere* from the glaſs, and depoſit it in a *glaſs receiver* covered in and outſide with tinfoil to within two inches of the top, and a *wheel* to put the cylinder in motion, is called the *electric machine*, or *fire pump*; when this machine is put in motion, it deſtroys tha equilibrium of the *electric fire* about it, and from thence the whole of its phænomena proceed, as may be proved by experiment. 1. If a perſon touch the electrified conductor, the fire will eſcape through the perſon into the ground with a flaſh and report. 2. If any number of perſons take hands, and the firſt perſon holds a chain which communicates with the *outſide* of the receiver, and the laſt perſon touches the communication with the *inſide* when the phial is charged, the fire will reſtore itſelf through all the company at the ſame inſtant, giving each a ſevere ſhock at the wriſts and elbows, in its paſſage back again to the *outſide* of the phial. 3. If a perſon ſtands on a ſtool with *glaſs feet*, and holds a chain faſtened to a conductor, on turning the machine, and touching him, ſparks may be brought out of every part of his perſon and cloaths, and if he touch warm ſpirits or gunpowder with his finger, they will take fire; which ſhews that the electric fire is chiefly pumped from the earth, and cannot return to it again through glaſs. 4. If a ball be hung on the conductor, and a plate of *bran* or *leaf gold* be placed under it, on electrifying the ball, the bran will be alternately attracted to and repelled from it in a beautiful ſhower; here, the particles of the bran are carriers as it were of the electric fire from the ball to the plate: And if two *bells* be hung on the conductor, one by a flaxen thread, and the other by a ſilk thread, (having from it a chain to the table) if a ſmall *clapper* be hung between them on a ſilk thread, it will carry the fire from one to another, and thereby ring both. 5. *Electrified feathers* ſpread out their threads radically; if a round body be held to them they *cling* to it and depoſit their fire; but if a point be held near them they ſhrink at once; hence the reaſon why the wire conductors riſing from the ground above the tops of houſes, terminate in points to receive with more eaſe the *lightning* from the clouds, and thereby prevent its miſchief. 6. If *wires* fixed like the ſpokes of a wheel be ſuſpended on their centre, with their points bent all the ſame way, and in the plane of the circle; on being electrified, the effluvia flowing from the points will ſtrike ſo forcibly upon the air as to force the wheel round with great rapidity: Hence a ſimple and pleaſing electric orrery is put in motion,---and various mills and other devices. 7. *Water* and *ſalt* (like the cylinder and cuſhion) will collect the electric fire when put in motion; for one is an *electric*, and the other a *non-electric* body; hence the *ſea* itſelf becomes as it were an *huge electrical machine* when violently agitated by winds, collecting on its troubled ſurface the fire from beneath, and looking in the night as if it was all in flames. *Clouds* raiſed from a ſea ſo circumſtanced, muſt needs contain more of the electric fire than clouds raiſed from the land, or a calm ſea; if therefore two clouds meet, fraught with *unequal portions of this fire*, the cloud *more* electrified will depoſit its abundance in the cloud *leſs* electrified, and with a flaſh of lightning reſtore the equilibrium; this fire clearing the air, the adjoining air will ruſh in, and with a report called *thunder*, reſtore the equilibrium of the air. Some think putrid fiſh, others animalcula, or an eaſt wind, the cauſe of the luminous appearance of the ſea. If a cloud attracted by a neighbouring mountain contains *more* electric fire than the mountain, the lightning will dart from the cloud to the mountain, and vice verſa; hence if an electric cloud comes too near a *tower*, *tree*, *houſe*, *&c.* and they are not wet, the fire will deſcend on them in an effort to reſtore the equipoiſe, and if greatly obſtructed in its paſſage to the earth, will perhaps break them all to pieces; to be dry, or ſtand under a tree or ſhed, is therefore dangerous in a thunder-ſtorm; and ſhews alſo the extreme utility of having a wire from the top of any tall building, down which the equilibrium will be reſtored without danger; and if the wire does not touch the ground, a finger at that time applied to the wire, will receive the *electric flaſh* much ſtronger than by a machine. A *kite* ſent up into the thunder-cloud by a wire, having a key tied to its end, and held by a ſilk ribband, will extract the fire from the cloud; it will come down the wire, and ſtream off the key to the ground in a beautiful, but alarming torrent of fire.

'Tis thus, by weight and meaſure, the ALMIGHTY has appointed ſelf-phyſic for the diſorders of his works!

If a *capillary ſyphon* be made to decant water, it will fall from it in *ſmall drops*, but if the water be electrified it flows from the ſyphon in a *ſwift ſtream*. Hence 'tis found that a perſon *poſitively electrified*, (i. e. having more electric fire thrown into him than his *natural quantity*, by ſtanding on a cake of wax, or a glaſs-footed ſtool, and touching an electrified conductor) has his *pulſe accelerated.* This acceleration has been found of great ſervice in *obſtructions*, *rheumatiſms*, *palſies*, *&c.* and the *electrical ſhock* has been ſtill more ſucceſsful in removing *paralytic complaints*, *deafneſs*, *tooth-ach*, *numbneſs*, *&c.* But its *medical qualities* have not yet been well aſcertained. A perſon inſulated and communicating with the inſulated rubber, loſes his natural portion of electricity, and his pulſe is lowered.

The electrical fluid always goes the neareſt way, and chuſes the beſt conductors. A chain hung on a wall, and made part of the circuit from the *in* to the *outſide* of the charged Leyden vial, is luminous when the vial is diſcharged, and ſhews the road taken by the electrical fluid: but if a ſtraight wire touch the two ends of the chain, the chain will not be luminous, for the fluid will run inviſibly through the wire, as being the *nearer* road. If the wire be then removed, and a ſtick put in its place, the chain again becomes luminous in the diſcharge, as the fluid will rather go a longer diſtance than paſs through a bad conductor.

The electrical fluid poured on the inſide coating of a Leyden vial, propels an equal quantity from the outſide. 1. The outſide coating of a vial being pieces of tinfoil not touching one another, the fire will be ſeen darting from one piece to another, till the charge is compleated: when diſcharged the fluid will return, and make the whole outſide luminous. 2. A bottle, coated on both ſides, having a cap cemented on its neck, with a valve, and from that cap a pointed wire going ſtraight into the bottle: If this bottle be exhauſted of its air, the vacuum will be found a good conductor; and when the cap is held to the prime conductor, flames like the Aurora borealis will iſſue from the point of the wire to the inſide coating, and charge it;—but while an imperfect communication is made between the negative outſide and the poſitive inſide, the point receives the fluid and exhibits only a ſtar on its point:—Hence a *receiving* point always exhibits a *ſtar*, and a *delivering* point *flames* in vacuo. A vacuum being ſo good a conductor, may not the ſun's heat and the great centrifugal motion of the equatorial parts of the earth, make the air there ſo thin, as to become a conductor of that electric matter of which the earth is the known reſervoir? and being thus thrown up into the upper regions of the atmoſphere, may it not make its way towards the poles where the ſmall degree of centrifugal force is friendly to its reception? Aiming therefore at a point, may it not be ſo far concentrated and condenſed, as to become viſible, and make thoſe radical coruſcations we call *ſtreamers*? for electric matter ſtreaming through highly rarefied air exhibits the very ſame appearance. 3. On the cover of a large Leyden jar fix a ſmaller jar, ſo that the *outſide* coating of the ſmall jar may have a metallic communication with the *inſide* coating of the larger;—the outſide coating of the ſmall jar becomes a conductor to the inſide of the big one, when held to an excited prime conductor; if when charged, one knob of the diſcharging rod be applied to the negative ſide of the large jar, and the other applied to the knob communicating with the inſide of the ſmall jar, a flaſh will iſſue from the contact (being the natural electricity of the inſide coating of the ſmall jar) and by which the equilibrium of its two ſides becomes deſtroyed. Electricity will then riſe from the inſide of the large jar upon the outſide of the ſmall one, and a communication between the *outſides* of the two jars produces another flaſh. By repeating this twenty or thirty times, the whole charge of the lower jar will be taken piecemeal out; and prove that what electricity is poured on one coating of a jar propels a like quantity from the other. 4. If a rod of wire, 18 inches long, having a light knob at each end, and ſuſpended on an inſulated point, be placed ſo between the knob of a charged jar and a metal pillar, that when one knob touches the pillar, the other may be ſix inches from that of the jar, then will the rod vibrate between the jar and the pillar, taking out the electricity ſo by little and little, as to acquire ten minutes to compleat the diſcharge. 5. If a Leyden vial be charged on an inſulated ſtool, having two pith balls hanging by fine threads projecting from its in and outſide coatings, the balls communicating with the poſitive coating will ſeparate; if then a finger touch the wire on which they hang, theſe balls will cloſe, and thoſe will open which communicate with the *negative* coating; touch that wire and the negative balls cloſe, and the *poſitive* balls open, &c. for an amazing number of times! ſhewing, that tho' glaſs will not conduct electricity, its influence can opperate through the thickneſs of glaſs. 6. To ſuperinduce electricity on a looſe coating laid on plate-glaſs, touch the coating with the knob of a charged vial, then ſhake off the coating, and clap an inſulated metal plate on the place, touching it at the time of contact, then lift up the plate, and it will give a ſpark to the knuckle; place it on the glaſs again, and touch and remove it as before, and it will give another ſpark, and continue to do ſo as long as the apparatus is kept clean and dry; making perpetual electricity, by which vials may be charged, inflammable air-guns fired, &c.—N. B. The plate of glaſs muſt have a fixed coating on the oppoſite ſide to the looſe one, and of the ſame ſize. This apparatus is called *Electrophorus*; and often inſtead of glaſs, a plate is made of ſulphur, ſhell-lac, roſin, &c. 7. To prove that the natural electricity of bodies may be diſturbed by the near approach of excited electrics, let two projecting arms of inſulated wood have ſlips of tinfoil glued on them from end to end, and pith balls hanging from one end of each; if the two arms be placed in a line, with the ball-end of one touching the end without balls of the other, and an excited electric be held within an inch of the end without balls, then will all the four balls part;—at that inſtant, if one ſtand be ſeparated from the other, the balls of one will be found in a negative and the other in a poſitive ſtate, the balls fartheſt diſtant from the excited electric will be in the ſame ſtate as the electric, and of courſe repelled by it; the neareſt attracted, &c. Hence if any part of an electrical cloud comes near the earth, it will diſturb its own kind of electricity in the earth, and drive it away; but if any other part of the cloud comes within the ſtriking diſtance of any conductor to the earth,---the cloud will be diſcharged, and the diſturbed electricity will return with a force that frequently proves fatal to animals in its way.

Electricity is applied to *inflamed eyes*, *tumours*, *&c.* by a chain coming from the prime conductor ending in a point of hard wood; the point is held near the part by a glaſs handle, and an aura iſſues from it on the ſore, that often performs a cure. 2. Paralytic and rheumatic patients are relieved by ſhocks ſent through the ſide affected. 3. Obſtructions are often cured in the female ſex by poſitive electrification, *i. e.* by placing the patient on an inſulated ſtool, communicating with the prime conductor, and keeping her electrified for half an hour together, occaſionally drawing ſparks from her.

LECTURE IX.

OPTICS.

Hail holy light! *Offſpring of heaven! Firſt born!*
Or of th' eternal coeternal beam;
May I expreſs thee *unblam'd?* —— MILTON.

THIS *modeſty* of the *poet* becomes the dignity of ſo divine a ſubject.—*Light* is the bleſſing which gives poignancy to all others, --- therefore the ſcience of *optics*, which immediately treats of it, muſt reflect part of its luſtre and importance. Plato defines light, "*a rare and ſubtil flame*;" and perhaps it is but diluted or very rare phlogiſton, or flame in a ſtate of great thinneſs or rarefaction. May it not be the inflammable principle perpetually let looſe from the ſun, and occaſionally from other luminous bodies? --- May not theſe phlogiſtic particles flowing from the ſun, enter into the texture of other bodies, give them the power of inflammability, and become fixt in them, till let looſe by the contact of bodies in actual inflammation? --- Or finally, that the concreted rays of the ſun in bodies having affinity with them, may give them the power of inflammability univerſally? Some believe *light* to exiſt even in the *abſence* of a luminous body, and that it is only a *luminous body* that puts it in motion. The moſt general, and probable opinion is, that it flows immediately *from* the luminous body in ſtraight lines, in all manner of directions, and conſiſts of *particles* ſo infinitely ſmall, as to exceed all human comprehenſion. A proof of this ſmallneſs is, that a *candle* will fill a ſphere of four miles in diameter, without the leaſt ſenſible loſs of its ſubſtance: And if a *row of candles* ſtand parallel to a *black paper*, with a *pin-hole* in it, each candle (through that hole) will make a ſeparate ſpeck on a *paſte-board* a little behind it. Theſe particles by ſtriking the *retina* of our eyes, excite in our minds the idea of light: And when they fall upon bodies, and are by them reflected to our eyes, they excite in us an idea of theſe bodies.

In a room *perfectly dark*, if the hand (or any thing) be put into light, and then taken into the dark room, it will be luminous ſome time, as if covered with phoſphorus.---Calcined oyſter ſhells taken out of the light into the dark room, exhibit the colours of the rainbow, &c. ſhewing that light ſtriking upon bodies, excites their latent light, and makes it viſible, as one candle is lighted from another.

We cannot ſee through the bore of a bended pipe; which proves that light moves in ſtraight lines in *every medium* of *uniform denſity*. But when they paſs *obliquely* out of one medium into another, which is either more *denſe*, or more *rare*, they are *refracted*, or bent towards the denſer medium, more or leſs, as they fall more or leſs obliquely on its ſurface. To prove which, put a *ſhilling* in the bottom of an empty veſſel; ſtand ſo far from it that the veſſel may hide the ſhilling; if water be then poured into it the ſhilling will again be ſeen. Hence we are deceived in the depth of water: A ſtraight ſtick put into water will appear crooked; and hence the *ſun*'s rays being broken by paſſing thro' our atmoſphere, we ſee him in the *horizon*, before he riſes, and after he ſets in it. When *rays* fall perpendicularly on any medium, they paſs ſtraight through without any refraction.

Glaſs is generally ground into eight different ſhapes for optical purpoſes. 1. A *plane-glaſs*, is flat and even on both ſides, and of an uniform thickneſs; will refract the rays of light, but not collect them into one focus. 2. A *plano-convex*, is flat on one ſide, and convex on the other. When parallel rays fall directly upon it, they paſs through it, and are ſo refracted, as to unite in a point called its focus, juſt ſo far behind it, as is equal to the diameter of the ſphere of which it is a part. 3. A *double-convex*, is convex on both ſides: Parallel rays paſſing through it *converge* or meet in a focus, at half the diſtance they do through the *plano-convex*; and as the heat of all thoſe rays are collected in that focal point, it will burn. 4. A *plano-concave* is flat on one ſide and concave on the other. 5. The *double-concave* is hollow on both ſides, and parallel rays paſſing through, *diverge* or ſpread out agreeable to the laws of refraction. 6. A *meniſcus-glaſs* is convex on one ſide, and concave on the other. 7. A *flat plano-convex*, or multiplying-glaſs, has its convex ſide ground into ſeveral flat ſurfaces. And, 8. The *priſm* has three flat ſides, and viewed endwiſe appears like an equilateral triangle. The *priſm* held obliquely to a ray of light in a dark room, will affect its ſmalleſt *particles* the *moſt*, and ſhew them to be a fine *indigo colour*; it will aſſemble the next in ſize cloſe to the firſt, and ſhew them to be of a *violet colour*; the next *blue*; the next *green*; the next *yellow*; then *orange*; and at laſt the *red*, which conſiſts of the largeſt particles, and therefore by the momentum of their motion, the leaſt capable of being attracted out of their way. 'Tis wonderful that theſe colours occupy ſpaces on the ſcreen on which they are thrown by the priſm, exactly proportionate to the diatonic ſcale of the *ſeven notes of muſic!* If in the rays ſo divided a *double-convex lens* be put, it will bring them into one point that ſhall be perfectly white; which accounts for the *white appear-*

ance of the atmoſphere, becauſe rays are ſo well mixed in it. As *white* is therefore a compoſition of all colours, ſo *black* is a privation of them all, and properly *no colour*, and ſuch a blank exiſts in the ſpace above our atmoſphere: In looking up therefore we ſee what is called the *blue ſky*, a colour naturally reſulting from the mixture of *black* and *white* through which we look. All bodies appear of that colour whoſe rays they reflect moſt; as a body is red when it reflects the *red rays*, and abſorbs the reſt. Two, or more, colours that are quite tranſparent by themſelves, become dark when put together. Thus, if *ſpirits of wine* be tinged *red*, and put in a ſquare bottle, every object ſeen through it will be *red*; becauſe it only ſuffers the red rays to paſs through it, and ſtops the reſt. If another bottle be tinged blue, all objects viewed through it will be blue for the ſame reaſon: But if the two bottles be held together, the object can no more be ſeen through them; for whatever rays paſs through the bottle next the eye will be ſtopped by the other, &c. Rays of light ſuffer different degrees of refraction, by falling more or leſs obliquely on the *priſm*, a *convex lens*, *&c.* and are thereby ſeparated as above; this happens to them in paſſing through *drops of falling rain:* For being *reflected* towards the eye from the ſides of thoſe drops which are fartheſt from the eye, and again *refracted* by paſſing out of theſe drops into the air, they come in refracted directions to the eye, and make all the colours to appear ſucceſſively in the form of a fine arch in the heavens, which is called the *rainbow:* All drops paſſing through an ideal plane in the ſhower, refract a certain colour to the eye—paſſing through another a little lower they refract another, &c. ſo the bow appears permanent.

Light is *reflected* by the *repellent* quality of bodies, and flies back from poliſhed ſurfaces, like a ball thrown againſt an hard and ſmooth plane: If a ſtick ſtand perpendicularly on that plane, and the ball be thrown obliquely on the plane near its foot, it will rebound on the other ſide the ſtick, and form an angle with it, equal to that in which it was thrown; the firſt of theſe is called the *angle of incidence*, and the other the *angle of reflection.* If upon a *plane looking-glaſs* a ray falls from any object, if a perpendicular be erected there, and the eye go off ſuch a diſtance as to form the *ſame angle* on the other ſide of it, the object will be ſeen in a ſtraight line behind the glaſs,---for it is an axiom in Optics, *that we always ſee objects in that line of rays that come to the eye laſt.* Hence I ſee my whole perſon in a glaſs but *half* its length; for the rays from my feet ſtriking upon the bottom of the mirror, will form the *angle of reflection* in my eye the ſame as if it was the *whole* length, &c. Hence alſo the effects of *diagonal mirrors*, *opera glaſſes*, *cameras*, *&c.* Parallel rays falling on a *concave mirror* will be reflected alſo agreeable to thoſe *angles*, and meet in a point at half the diſtance of the mirror, from the centre of its concavity; if the rays proceed from an hot ſun, his image will likewiſe be found in that point, and burn. The rays which proceed from any *terreſtrial object*, *come diverging* to the mirror, and therefore will not be *converged to a point* at half the diſtance of the mirror's ſurface from the centre of its concavity, but *nearer to that ſurface*; the image will be leſs than the *object*, but will be ſeen *inverted*, and hanging pendant in the air, quite diſtinct by an eye placed oppoſite the mirror. If the *object* be *in* the *centre of the mirror's concavity*, the *image* and *object* will be *together*, and of *equal bulk:* Therefore when the object is more remote than the centre of concavity, the *image* will be *leſs* than the *object*, and between the *object* and *mirror:* But when the object is *nearer* than the centre of concavity, the *image* will be *more remote*, and *bigger* than the object. The angles of *incidence* and *reflection* alſo account for the *ſmall image* in a *convex mirror.*

The *human eye* is lodged in a bed of fat, and ſecured in an hollow orb of bone; ---'tis moved by *muſcles* which act on its outſide like *pullies*, and conſiſts of *four coats*, and *three humours*. The coat, in which the *back part* of the eye is contained, is called the *ſclerotica*; it is a *large portion of a globe*, very ſtrong, and of a non-elaſtic nature; ---that part which *completes the globe* on the *fore-part* of the eye, is the *cornea*; it bulges a little forward out of that ſhape, and is a fine tranſparent membrane. Next within the ſclerotica is that called the *choroides*, which ſerves as it were for a *ſoft lining* for the other; and within this, is ſpread a fine expanſion of the optic nerve, like a net, called the *retina*, upon which are painted, as in a *camera obſcura*, *the images of all viſible objects*, *by the rays of light that flow from them*: The *iris* is compoſed of two ſets of muſcular fibres, which dilate, or contract the *hole* in it called the *pupil*, ſo as to adapt it to a ſtrong or weak light. The *adnata*, or *conjunctiva*, is the white of the eye, a fine membrane that *folds under the eye-lid*, and joins to it. Under the *cornea* is a fine tranſparent fluid like water, and thence called the *aqueous humour*: It gives the protuberent figure to the cornea, and goes through the pupil. Behind this lies the *cryſtalline humour*, ſhaped like a double-convex glaſs, tranſparent as cryſtal, of the conſiſtence of hard jelly, and which converges the rays that paſs through it to a focus on the *retina*. It is incloſed in a fine tranſparent membrane, from which proceed radical fibres called the *ligamentum ciliare*, all round its edge, and joined to the out edge of the *iris*: Theſe fibres, by a power of contracting and dilating, alter the convexity of the *cryſtalline humour*, and ſhift it a little *backward* or *forward* in the eye, to ſuit it to the different diſtances of objects (*an admirable proviſion!*) The *cryſtalline humour* is bedded on the *vitreous humour*, which fills the whole orb of the eye, and is tranſparent like glaſs; the largeſt of all in quantity, and is much of a conſiſtence with the white of an egg. The *optic nerve* comes from the *brain*, through the *ſclerotica* and *choroides*, on that ſide the eye next the noſe; and is incloſed on the outſide the eye by coats proceeding from the *pia* and *dura mater*, and of which the *ſclerctica* and *choroides* are but a continuation. Theſe are the parts of this wonderful organ.

Rays from any *object* ſtream upon the *retina*, and there paint it invertedly, as may be ſeen by cutting off the three coats from the back part of a freſh bullock's eye, and putting a piece of white paper over that part: If the eye is then held before any bright object, an inverted picture of it will be painted on the paper. The *optic nerve* incloſes a *blood-veſſel*, which renders objects inviſible that fall on it; how wiſely therefore is it placed on one ſide of each eye! that the ſame parts of an image which fall on the optic nerve of *one* eye ſhould not fall on the *other*! If three patches are placed at a foot diſtance from each other on a wall, if the *right* eye be covered, and the *left* look ſtedfaſtly at the right-hand patch, that on the left hand will diſappear, becauſe it falls on the artery in the optic nerve.

The nearer any object is to the eye, the larger is the angle under which it is ſeen; therefore an object looks twice larger at *one* than at *two* miles diſtance. Hence the uſe of *convex glaſſes*, which, by increaſing *this* angle, make *minute objects* viſible; and when the *humours* are grown ſo flat in decayed eyes, that the picture falls behind the retina, can bring the rays to converge ſo that the picture ſhall be brought back as it were to the *retina*. Hence alſo the reaſon that the *too round* eye requires the *double concave* glaſs, by its divergency, to remove the image from the vitreous humour forward to the retina.

The *ſingle microſcope* is only a ſmall convex glaſs, having the object placed in its focus, and the eye at the ſame diſtance on the other ſide. Its magnifying power is thus calculated: A good eye cannot ſee any object diſtinctly at leſs than ſix inches diſtance; if this be divided by the focal diſtance of the glaſs, the quotient will be how much the diameter of the object is multiplied.

The *double microſcope* conſiſts of an *object glaſs* and an *eye glaſs*, between which the image is formed and magnified, by having the object a little further from the object glaſs than its principal focus; this image, brought ſo near, is viewed by the eye through the eye glaſs. If each glaſs magnifies *ſix times* (as by the laſt calculation) then is the object magnified *thirty-ſix times* by both. This inſtrument is equipt with a mirror which, by the *angle of incidence* and *reflection*, throws up light on the *underſide* the object; which object being placed in the focus of a *moveable lens*, has its *upperſide* enlightened alſo.

The *ſolar microſcope* is placed in a round hole in a ſhutter that only admits, into a dark room, a ſmall cylinder of rays; that theſe rays may be ſent ſtraight through the tube, a plain mirror on the *outſide* is ſo fixed as to reflect them in; they then paſs thro' a large convex lens; after which, they fall upon, and enlighten the object, which is placed in the focus of a *ſmall magnifier*, through which they carry a large inverted image of the object to a white ſheet, placed at any diſtance for its reception.

A *refracting teleſcope* may be made of *two convex glaſſes*, viz. an *object glaſs* and an *eye glaſs*, if the focus of the *eye glaſs* be in the ſame part of the tube where the image is formed by the *object glaſs*; but then the image will be inverted and therefore 'tis only ſuitable for celeſtial objects. The magnifying power of this teleſcope is as the focal diſtance of the *object-glaſs* to the focal diſtance of the *eye glaſs*: Therefore if the *former* be divided by the *latter*, the quotient will expreſs the magnifying power, and ſhew, that if the focal diſtance of *each were alike*, the magnifying power of the teleſcope would be nothing; and that this magnifying power will increaſe with its length, for the greater the focal diſtance of the object glaſs, the leſs may be the focus of the eye glaſs.

A *refracting teleſcope*, that will ſhew objects in their natural poſture, muſt have *two equal convex glaſſes* added to the eye glaſs, and all three muſt ſtand at double their focal diſtances from one another. As theſe three do but as it were compoſe one eye glaſs, the magnifying power of this teleſcope may be calculated as the laſt.

Dollond's patent teleſcope is formed on the ſame principles, only its object glaſs is much larger, and is compoſed of two joining glaſſes of different denſities, one a *plano-concave*, and the other a *double convex* that fits into the other's concavity. Theſe make the field of view larger, and, by taking off the coloured rays, the image becomes bright, and quite diſtinct: For as the rays which paſs through the *edge* of a *convex glaſs* are more *unequally refracted* than thoſe that paſs nearer its *middle*, they don't meet in the ſame point, but form a circle of priſmatic colours round the image: In the *common teleſcope theſe* are partly taken off by a *black plate* fixed in the tube, with an hole through its centre; but the *patent glaſs* does this much more effectually.

The *reflecting teleſcope* exceeds all others in its *magnifying power* and *portable ſize*; and its outward figure conſiſts of a great and ſmall tube, ſcrewed into the end of one another. At the bottom of the great tube is placed the large concave mirror, with an hole through its middle. Parallel rays from celeſtial objects falling on this mirror, are reflected back by it, and form the *image* a little ſhort of the *ſmall concave mirror* which faces the hole in the large one. From this image the rays diverge to the ſmall mirror, and are from thence reflected parallel, and inverted into the ſmall tube, through the hole in the large mirror : here meeting with a convex lens, they are ſo refracted as to form the image in the *ſmall tube.* The *image being now brought ſo near*, requires nothing but a ſingle, or compound, *eye glaſs* to ſend it duly magnified to the retina. Rays from any terreſtrial object *will not come parallel* but converge a little ; hence the image is formed nearer the great mirror, and therefore a ſcrew is fixed to the ſmall mirror, on the outſide the tube, to adjuſt it to it ; and alſo to the *greater or leſſer convexity* of different eyes. Mr. Herſchal's reflector is formed on the Newtonian plan, viz. its great mirror is not perforated, and therefore its image is received by a plane mirror placed diagonally within the tube, and which ſends that image through the magnifying or microſcopic part fixed perpendicularly in the tube. The excellence of this inſtrument conſiſts in the *curvature* and *poliſh* of its great mirror, which forms the image of the object looked at *ſo perfect*, that a magnifying power of 6,500 can be applied to it.

The *diagonal mirror*, for viewing prints, is a pleaſing inſtrument. If a *plane mirror* be placed at an angle of 45 degrees above a print lying horizontal and inverted, it will turn the rays reflected from the print into an horizontal direction to the eye : If then a *large convex lens* be placed between the eye and the mirror, the picture will be prodigiouſly magnified ; and if an aſſemblage of *ſhell-work* environ the view between the *print and the mirror*, the picture will have a beautiful frame to it.

The *camera obſcura* is formed on the ſame principles. A *diagonal mirror* is ſet at the ſame angle againſt the landſcape, and reflects it downwards through a *convex lens* into a *dark box*, where it is painted on a *white paper* placed in the focus of the lens, and on which a hand put into the box may draw the landſcape to the minuteſt exactneſs.

The *opera glaſs* is alſo formed of a ſmall diagonal mirror, which ſends the rays through a convex glaſs to the eye. Through this a gentleman may look at a diſtant lady in the company, and the lady know nothing of it.

The *magic lanthorn* is formed on the ſame principles as the *ſolar microſcope*; a candle ſupplies the place of the ſun; and having its rays tinged with the colours of *tranſparent figures painted on glaſs*, throws them through two convex lenſes on a white wall in a dark room, prodigiouſly magnified.

LECTURE X.

USE of the GLOBES.

WHEN a ſhip approaches us at ſea, the firſt part of her we ſee is her *upper ſails*, after that we ſee her *lower ſails*, and then the *hull*:—'Tis evident ſhe moves on a round ſurface or we ſhould ſee the whole at a time. In ſailing from capes we loſe ſight of them firſt at the *bottom*, then the *middle*, and at laſt the *top* diſappears. Theſe effects are in all parts of the world. Several perſons have ſailed round the earth. And all the bodies in the ſyſtem are round. Hence we conclude that the *earth is a globe* alſo.

The earth's roundneſs is no more affected by the largeſt mountains, than the roundneſs of a common globe is by a few grains of duſt thrown upon it; for they bear no greater proportion to its bulk. It is 7,970 miles in diameter: Near 100 millions of miles from the ſun: Moves round him in 365 days 5 hours and 49 minutes, at the rate of 60,000 miles an hour; and turns round upon its axis every 24 hours, from weſt to eaſt, which makes all the heavenly bodies ſeem to turn round the contrary way, or from eaſt to weſt.

The particles of which the earth is compoſed would fly into confuſion, if not held together in the form of a globe by the *power* of *gravitation*. 'Tis this power which gives *weight* to all bodies, or that tendency they have towards the centre of the earth. Hence the general *top* of the earth becomes its whole ſurface, and the general *bottom* its centre. The *Antipodes* are therefore as much on the top as we. But as the parts of the earth are looſe, the violent motion it has on its axis will in ſome degree overpower even the force of gravity, and accumulate more matter round the *Equator*, becauſe the *centrifugal force* is greateſt there; hence the true figure of the earth is an *oblate ſpheroid*, or like an orange, 35 miles more in diameter at the equator than at the poles. This was proved by an actual menſuration, and is explained by the whirling rings.

This oblate figure proves its *diurnal motion*; if it was at reſt it would be neceſſarily a perfect ſphere. We perceive not this motion, becauſe the *air*, in which we live, partaking of the general gravitation, is carried round along with the earth. When a ſhip turns round, if we look out at the cabin windows, we believe ourſelves at reſt, and the neighbouring country turning round us; —we are deceived in like manner in the motion of the earth.

Where there is no reflection from contiguous objects, a globe can but be *one half* enlightened by a luminous body; hence, if a globe turns round, there muſt be a ſucceſſion of light and darkneſs, or day and night, to its inhabitants.

Had a globe no other motion, there could be no variety in its ſeaſons or length of days. As gravity decreaſes according to the ſquares of the diſtances, it follows that if one body move round another as its centre of motion, the ſquare of its periodic times will be as the cube of its diſtance from that body; this holds preciſely with regard to the planets and their moons.——The planets ſometimes appear to *ſtand ſtill*, ſometimes to *go backwards*; this muſt always be the caſe where one body moves nearly in the ſame plane, and circular within that of another moving body. The eclipſes of Jupiter's ſatellites appear later to us by 16 minutes at one time of our year than at another. 'Tis matter of obſervation that all the planets revolve round the ſun. From all which we are certain that the earth goes round the ſun, and not the ſun round the earth.

We know the path our earth deſcribes in the heavens, by obſerving *that* which the ſun ſeems to deſcribe in the oppoſite part of the heavens. We find one ſtar without any apparent motion, ſituated 23 degrees and a half from the axis of this orbit, and which is occaſioned by being oppoſite to one of the poles of our earth, and thence called the polar ſtar; hence we diſcover that ſublime contrivance the inclined axis of the earth, which keeping always *parallel to itſelf*, occaſioning the different ſeaſons, and different lengths of day and night; diffuſing equally, over the face of both hemiſpheres, the bleſſings of the ſun.

The axis ſo diſpoſed will neceſſarily bring the northern and ſouthern parts of the earth alternately to the ſun, therefore when it is ſummer in the *north* it will be winter in the *ſouth*, and vice verſa. So far on each ſide the equator as the ſun at any time of the year ſhines vertically, is called the *torrid zone*, and it is bounded by two imaginary lines; *that* to the north is called the *tropic of cancer*, and *that* to the ſouth, the *tropic of capricorn*. When the ſun ſhines vertically over the firſt, he muſt ſhine 23 degrees and a half further than the north pole, and will not therefore ſet for many days together to the inhabitants of the *north frigid zone*,—but it will be then total darkneſs (the ſame time) to thoſe of the *ſouthern frigid zone*; hence the poles *muſt* but have one day and one night in the year. Theſe two zones are bounded by lines alſo, the north called the *artic*, the ſouth the *antarctic* circle. The intermediate ſpaces between the torrid and frigid zones are called the *temperate zones*.

In the northern hemiſphere the *vernal equinox* (or equal day and night in the ſpring) is on the 20th of of March; and the *autumnal equinox* is on the 23d of September: In the ſouthern hemiſphere the contrary. At the equinoxes the ſun ſhines over the equator; at the *ſolſtices* he is 23 degrees and a half from the equator.

The *meridian* of any place is a ſemicircle paſſing through it, cutting the equator at right angles, and terminating in the poles. The earth's circumference is 360 degrees, each near 70 Engliſh miles, and as the earth turns round its axis in 24 hours, each meridian revolves 15 degrees in an hour, for 24×15=360. Therefore every place to the *eaſtward* of another has its hours ſooner; if *weſtward*, ſo much later.

The *longitude* of any place is the number of degrees between its meridian, and the meridian of any place, from

whence

whence the longitude is reckoned, and is deemed *eaſt* or *weſt* according as it is ſituated. The eclipſes of *Jupiter's ſatellites* afford a method of finding the longitude, thus; ſuppoſe an eclipſe of any *ſatellite* happens in London at ſix in the morning, and that it is ſeen at another place at four in the morning, the difference of time is two hours, which anſwers to 30 degrees weſt of London. Theſe obſervations the motion of a ſhip hinders from being made at ſea;—and hence may be perceived the extreme utility of a regular time-keeper.

The *latitude* of a place is ſo many degrees as it is from the equator; if to the north, it is ſaid to be in *north latitude*; if to the ſouth of the equator, in *ſouth latitude*;—hence by the lines of latitude and longitude, the face of a globe is covered with *imaginary ſquares*, by which the ſituation of every ſpot on the face of the earth is as exactly aſcertained as the parts of an eſtate are by its hedges and ditches.

The *rational horizon* of a place extends 90 degrees from it on all ſides. The *ſenſible horizon* is the boundary of the obſerver's ſight.

The *ecliptic* is that circle in the heavens through which the earth makes its revolution 'round the ſun,—and it is diſtinguiſhed by conſpicuous fixed ſtars called ſigns or conſtellations, ſuch as *Aries*, *Taurus*, *Gemini*, *Cancer*, *Leo*, *&c.* The *zodiac* extends to eight degrees on each ſide of the ecliptic, and with it round the heavens.

The four continents of the earth are *Europe*, *Aſia*, *Africa*, and *America*. The oceans are the *Northern*, the *Atlantic*, the *Ethiopic*, the *Indian*, the *Pacific*, and the *Southern Oceans*. The unknown parts of the earth contain 160,566,276 ſquare miles; the inhabited parts

38,990,569, i. e. Europe 4,456,065; Aſia 10,768,823; Africa 9,654,807; America 14,110,874. In all 199,556,845; which is the number of ſquare miles on the whole ſurface of our globe.

When a round ball has the different countries, kingdoms, towns, and rivers delineated upon it agreeable to their ſituations, it is a repreſentation of the earth. If an hollow ſpherical ball could have the fixed ſtars properly marked on its inſide, with the ſun, moon, and planets, it would be a repreſentation of the heavens to an eye placed in its centre; but this being inconvenient, the fixed ſtars are placed on an opake globe, and the ſun and planets repreſented by patches placed on the ecliptic, becauſe they are continually changing their places.

LECTURE XI.

On the MOON, *&c.*

THE *moon* is no planet, but only a ſatellite, or an attendant on the earth. The farther any planet is from the ſun, the more occaſion it has for ſuch an help to its light; hence Mercury and Venus are without moons, as being near the ſun; but Jupiter has four, and Saturn five, becauſe of their diſtance from it.

The moon's face abounds with great *inequalities*, and hence ſhe reflects a more chaſte and agreeable light than if her ſurface was ſmooth. She always keeps the *ſame face* towards us (ſome ſay becauſe the quality of that ſide of her is more adapted to catch the attraction of the earth than the other) and conſequently muſt turn once round on her axis, while ſhe goes once round the earth in her orbit. Her *periodical revolution*, or time of going round from one point of her orbit to the ſame point again, is 27 days 7 hours 43 minutes: But her *ſynodical revolution*, or time from change to change, is 29 days 12 hours 44 minutes;—this difference is cauſed by what the earth has advanced in the ecliptic during that time, which is 29 one-tenth degrees. *(Illuſtrated by the Orrery and Ferguſon's paradox.)*

The moon's diſtance, found by her parallax, is 240,000 miles. Her diameter 2180 miles,—and ſhe moves about 2290 miles every hour.

The *moon* has no light of her own, but only reflects the beams of the ſun, as a poliſhed body does the light of a candle;—hence, as ſhe is a globe, we muſt ſometimes ſee *more* ſometimes *leſs* of her enlightened ſide, *viz.* when ſhe is between us and the ſun, her dark ſide is towards us, and therefore ſhe diſappears; as ſhe advances forward we ſee a ſmall part of her enlightened ſide, and call it the *new moon*; before next evening ſhe is got a few degrees farther to the eaſt and we ſee *more* of her illumin'd ſide;---every evening we find her advanced till ſhe riſes in the eaſt in oppoſition to the ſun in the weſt, and then her whole enlightened face is towards us, and we ſay ſhe is at the *full*; her decline is from the ſame reaſons; and a ball over a gate enlightened by the ſun conveys a clear idea of both. *(Illuſtrated by the Orrery.)*

The earth is a *moon* to the moon, waxing and waning as ſhe does; it appears 13 times as large to the lunarians as the moon does to us, affording them both an uſeful and an amazing ſpectacle, for its continents and ſeas may be plainly perceived by them, as well as its rapid motion round its axis. *(Proved by the Orrery.)*

The planets as well as their ſatellites being *enlightened by the ſun*, muſt caſt *ſhadows* towards that part of the heavens oppoſite to the ſun. Was the earth bigger than the ſun, its ſhadow would ſpread and extend far beyond the orbit of Mars, and conſequently *eclipſe him*; for he is but 42 millions of miles from the earth, when they are in conjunction; but the earth's ſhadow never reaches him, therefore it muſt end in a *point* much ſhort of that diſtance; another proof how much the ſun is bigger than the earth: But the moon is eclipſed when ſhe falls into the earth's ſhadow, which, for the reaſons above, can never happen but when ſhe is at the *full*, becauſe that is the only time when ſhe is oppoſite to him; but was ſhe a *luminous body* ſhe could not be darkened by the earth's ſhadow. *(Proved by a real ſun and moon.)*

The ſun is eclipſed when the moon paſſes directly between him and any part of the earth; this can only happen at the *change of the moon*. *(Proved in like manner.)*

Was the moon's orbit in the *plane* of the earth's path round the ſun, ſhe would be eclipſed every time ſhe came to the *full*, and would eclipſe the ſun every time ſhe came to the *change*; but one half of her orbit is on the *north ſide* of the ecliptic, and the other half on the *ſouth ſide* of it, and muſt therefore cut the ecliptic in two oppoſite points called the *moon's nodes*. The angle of this orbit with the ecliptic is 5 degrees and one-third. *(Shewn on the Orrery.)*

When the moon is at full, above 12 degrees from either of theſe nodes, ſhe paſſes clear of the earth's ſhadow, and cannot be eclipſed; and when ſhe changes above 18 degrees from either of them, ſhe paſſes either above or below the ſun, and therefore cannot eclipſe him: But if ſhe be at full or change within thoſe diſtances, then an eclipſe happens, and if ſhe be *in* the node, the eclipſe is central. *(Explained by the Orrery.)*

If theſe nodes kept always in the *ſame* ſigns of the ecliptic, the ſun and moon would always be eclipſed in the ſame *places* and at the ſame *time* every year; — but the eclipſes *fall back* every year from the eaſt to the weſt, in ſuch a manner as to prove that the moon's orbit *moves backwards* 19 degrees one-third every year, ſo that in 18 years and 225 days there is a period or reſtitution of the ſame eclipſes; and they then appear in the ſame places and the ſame time as before. (*Illuſtrated by the Orrery.*

The earth and moon are chained to one another as it were by their *mutual attraction*, which, like the ſun and planets, is in proportion to their quantities of matter. If an heavy and light ball be tied to the two ends of a ſtring a yard long, and toſſed up into the air, they will form to themſelves a centre of gravity. On this centre of gravity the earth and moon revolve in *equilibrio*, and its diſtance from their centres is inverſely as their quantities of matter, *viz.* 6000 miles from the earth's; conſequently the centre of gravity forms the *real orbit*, and makes the earth 12000 miles nearer the ſun at the time of *full moon*, than at the time of change. This is demonſtrable by the ſun's appearing ſo much larger at the full than at the change of the moon. (*Proved by the whirling tables.*)

The further any part of the earth is from this centre of gravity, the greater is its tendency to fly off in a tangent,--- therefore the *ſide of the earth* which is turned away from the moon has a greater *centrifugal motion* than its *centre* has: And this *centre* a greater than *the ſide* next the moon. At the earth's *centre*, the moon's attraction balances the centrifugal force, but muſt be *ſtronger* than the centrifugal force of the *ſide of the earth next her*, and *weaker* than the centrifugal force of the *ſide fartheſt from her*. As the moon's attraction is greater than the centrifugal force on that ſide of the earth next the moon, of courſe the *tide* will riſe on that ſide: But as the centrifugal force on the oppoſite ſide is greater than the moon's attraction, the tide will alſo riſe on that ſide; hence the reaſon of *two tides* in 25 hours. *(Proved by the tide table)*.

The ſun agitates the water in proportion to the moon as 3 to 10; therefore, when the ſun and moon draw in the *ſame direction*, they cauſe a *ſpring tide*, and this happens at the change of the moon. If the earth had no moon, the ſun would cauſe a *ſmall tide* in its oceans, therefore at the full of moon ſpring tides happen as well as at the change, for the ſun's centrifugal tide being reinforced by the moon's attraction, and the moon's centrifugal tide by the ſun's attraction, ſpring tides happen both at full and change of the moon; but at the quarters when they attract in *contrary directions*, they deſtroy the effects of each other in a degree, and then we have *neap tides*. At the *equinoxes* the ſun and moon being both on or near the equator, their attraction is more in a *line* than at moſt other ſeaſons, hence the *prodigious tides* which generally follow theſe ſeaſons. A planet alſo falling in conjunction with the ſun and moon, will increaſe the tides ſtill more. *(Shewn by the tide tables.)*

The *air* being a fluid much lighter than water, is more affected by the moon's attraction; and we find that people diſordered in their ſenſes are much worſe when the ſpring tides are in the air, which tides are, as in the other element, at the full and change of the moon.

To the inhabitants ſituated at a conſiderable diſtance from the equator, the *different parts* of the ecliptic riſe at very *different angles* with the horizon. In northern latitudes, the ſigns *Piſces* and *Aries* riſe with the *ſmalleſt angles*; *Virgo* and *Libra* with the *greateſt*; therefore when the moon is in *Piſces* and *Aries* ſhe muſt riſe nearly at the *ſame hour* for ſix or ſeven days together. In *winter* the moon is in thoſe ſigns about the time of her firſt quarter,

but

but as ſhe muſt then riſe about *noon*, *that* riſing is not taken notice of. In *ſpring* the moon is in them about her *change*, but as ſhe then gives *no light*, her riſing is alſo unnoticed. In *ſummer* ſhe riſes in *Piſces* and *Aries*, about her *third quarter*, but at twelve o'clock at night, conſequently the phænomenon is ſeldom *then* regarded; but in *autumn* thoſe ſigns are oppoſite to the ſun, and therefore the moon muſt be *full* in them, and, very uſefully for the farmers, riſes in their harveſt immediately after ſun-ſet for ſeveral evenings together, and thence acquires the name of the *harveſt moon*. (*Proved by the Orrery and Globe.*)

LECTURE XII.

ASTRONOMY.

THE planets are retained in their orbits by the *power of gravity*;---but as the ſun is by far the largeſt body in our ſyſtem, if no other power acted on them they would be *drawn down to the ſun*. All bodies therefore that move in curves, as the planets do round the ſun, muſt be acted upon by *two principles*; and motion being *rectilineal*, we ſuppoſe the Almighty gave each planet this kind of impulſe at its creation, ſo that between one power *drawing to the centre*, and another *acting perpendicular to it*, the planets are impelled in eliptic orbits round the ſun, as a pebble tied to a mill-ſtone, and thrown from the hand, would revolve round the mill-ſtone. An idea of this is given by a ball impelled ſingly in a ſquare in two directions, one perpendicular to the other; when both act they give the diagonal of the ſquare, &c.

Our ſyſtem muſt be conceived as within the concave ſphere ſeeming to be formed by the *fixed ſtars*, and the *ſun* as near the centre of it, an huge globe of fire, near a million of miles in diameter, and near 100 millions of miles from the earth, according to calculations made from the tranſits of Venus.---He turns round on his axis in 25 days and 8 hours, as may be ſeen by ſpots on his face; and was no doubt intended to give light, heat, and vegetation to the ſix primary and ten ſecondary planets which revolve round him.

All theſe planets move round the ſun from *weſt, by ſouth, to eaſt*, in orbits nearly circular, and almoſt in the ſame plane. The *comets* move in all manner of directions, in orbits which are very long ellipſes, much inclined to one another, and to the orbits of all the planets. The tails of comets are only thin vapours, for if they were flame no ſtar could be ſeen through them.

The time in which any planet goes round the ſun, is the *length of its year*, and the time in which it turns round on its axis, is *the length of its day and night* taken together, as repreſented on the Orrery.

The neareſt planet to the ſun is *Mercury*; he goes round him in 87 days 23 hours, is about 3000 Engliſh miles in diameter, and diſtant from the ſun 42 millions of miles; he moves in his orbit about 100 thouſand miles every hour; the length of his days and nights are unknown, being but 56 times the ſun's apparent diameter from him, he ſets and riſes too near the ſun for any obſervations to be made of his ſpots.

Venus goes round the ſun in 224 days 17 hours, her diameter is near 7,900 miles, her diſtance from the ſun is 79 millions of miles, her hourly motion in her orbit is 69 thouſand miles, and ſhe turns round on her axis in 24 days 8 hours of our time. By her axis inclining 75 degrees from a perpendicular to her orbit, ſhe has two ſummers and two winters at her equator.

Her orbit alſo deviates three one-half degrees from the plane of the ecliptic, ſo that ſhe has two nodes, or places where ſhe croſſes the ecliptic, one in the 14th degree of Gemini, and the other in the 14th of Sagittarius. If the earth happens to be in thoſe ſigns when *ſhe* is, then we ſee her tranſit over the ſun's face, a phenomenon which happened the 1ſt of April 1761, and gave the aſtronomers the opportunity of calculating the ſun's parallax (*viz* 7″40‴) and of conſequence his diſtance, as well as that of the planets.

The *earth* is the next planet in the order of the ſyſtem.

Mars, ſtill higher in the ſyſtem, is 167 millions of miles diſtant from the ſun, moves at the rate of 47,000 miles an hour, goes round the ſun in 678 days, and turns round on his axis in 23 hours 39 minutes and 22 ſeconds, at a medium, according to Mr. Herſchall's obſervations, on a ſpot on the face of Mars; though he obſerves his motion not to be regular. He is about one-fifth as large as our earth; his *red appearance* is occaſioned by a groſs thick atmoſphere with which he is ſurrounded, and which is ſuppoſed to ſupply his want of a moon.

Jupiter, the largeſt of the planets, is 570 millons of miles diſtant from the ſun, and above 400 millons from our orbit; he moves round the ſun in about 12 years of our time, at the rate of 30,000 miles per hour; he is near 90,000 miles in diameter (i. e. near 1000 times as large as our earth) is accompanied by four moons, ſome bigger and ſome leſs than the earth, which revolve round him as our moon does round us; and the faint ſubſtances on his face, called his belts, are ſuppoſed to be parts of his atmoſphere drawn into lines by his exceeding quick revolution on his axis, which is once in 9 hours 49 minutes.

Saturn, the ſecond in magnitude, and hitherto conſidered the moſt diſtant of all the planets, is 949 millions of miles from the ſun;—near 70,000 miles diameter;—moves at the rate of 18,000 miles per hour,—but is too remote for his ſpots to be ſeen. He is equipt with *five moons*, beſides *a broad luminous ring* which alſo reflects the ſun's light ſtrongly upon him. This planet is near 30 of our years in making his revolution round the ſun.

The *Georgium ſidius* (or rather the *Herſhall*) ſo called by its ingenious and indefatigable diſcoverer Mr. Herſhall; was firſt diſcovered near one of the feet of Gemini; its year is calculated to be 82½ of ours, its diſtance twice that of Saturn from the ſun, and its ſize 100 times as large as our earth.

Theſe calculations are the lateſt and moſt accurate that have been made; they are given in round numbers, to eaſe the memory; and are founded on *mathematical* as well as *occular* certainty.

By an *attempt* at the ſame kind of calculation to find the diſtance of the *fixed ſtars*, 'twas found *that the whole diameter of the earth's orbit would not make a parallax* or *angle with the neareſt of them!* Their diſtance therefore muſt be inconceivably great. Light diminiſhing as the ſquares of the diſtances increaſe, the ſun's rays therefore cannot enlighten the fixed ſtars; and a teleſcope which magnifies 400 times does not ſenſibly magnify them; 'tis therefore highly probable they are *ſuns* like ours, ſhine by their own unborrowed luſtre, were not intended for our ſervice, but to give light, heat, &c. to ſyſtems of worlds of their own, formed probably for the ſame purpoſes as ours, though too remote for our eyes aſſiſted by the beſt glaſſes to perceive. We find the worlds of our ſyſtem covered with *continents*, *ſeas*, *hills*, *&c.* Who can doubt therefore but they are inhabited, as well as all the worlds of the other ſyſtems ? How much too big is this idea for the human imagination ! By the late improved teleſcopes thirty thouſand of theſe ſuns have been found more than the naked eye can perceive ! --- were our glaſſes ſtill better, we ſhould, no doubt, find more --- 'tis not improbable there may be ſtars ſo diſtant that their light has not reached the earth ſince the creation. Many of thoſe ſtars appear double, and coloured green, blue, red, violet, &c.

Let us on the wings of imagination then launch into the immenſity of ſpace, and behold *ſyſtem* beyond *ſyſtem*, *above us*, *below us*, to the *eaſt*, the *weſt*, the *north*, the *ſouth !* Let us go ſo far as to ſee our ſun but a *ſtar* among the reſt, and our ſyſtem itſelf as a point, and we ſhall but even then find ourſelves on the *confines of creation !* How inadequate then muſt be the utmoſt ſtretch of human faculties, to a conception of that amazing *Deity* who made and governs the whole ! Should not the narrow prejudices, the littleneſs of human pride ſoften into humility at this thought ?

EXPLANATION

Of ſuch uncommon Words as cannot, without affectation, be omitted in this COURSE.

ABSORB, to drink in.
Acid, ſour.
Accelerated, haſtened, hurried forward.
Accumulate, to heap up.
Adheſion, the ſticking together.
Affinity, related to, having an affection for.
Alkali, fixed ſalt, or ſubſtances fermenting with acids.
Analogy, likeneſs, proportion.
Apparatus, inſtruments for experiments.
Attraction, a drawing together.
Axis, an axle on which any thing turns.

C

Capillary, ſmall as an hair.
Calcs, the earth or cinders of a metal.
Centrifugal, a direction given to a body different from that in clining to the centre.
Centripetal, tending towards the centre.
Coheſion, clinging or ſticking together.
Collateral, lying ſide by ſide.
Compreſs, to ſqueeze together.
Concave, ſpherically hollow.
Condenſe, to bring the parts of matter cloſe together.
Contact, touching each other.
Convex, ſwelling ſpherically outwards.
Converge, to draw towards a point.
Cryſtallization, ſalts ſhooting into their uſual forms.
Cylinder, like a rolling ſtone.

D

Denſity, compactneſs, cloſeneſs.
Diagonal, the line running between oppoſite corners of a ſquare.
Diverge, to ſpread out.

E

Ebullition, a bubbling like boiling water.
Elaſtic, having a ſpring.
Electrometer, an electrical gage.
Efferveſcence, a ferment or diſcharge of fixed air, a waxing hot.
Ellipſes, an oval line or ſurface.

F

Fibre, a ſmall ſtring.
Flaccid, lax, looſe, or flabby.
Fulcrum, a prop or point of ſupport.
Frigorific, chill, or cauſing cold.

G

Gravity, weight, or the tendency one body has to another.

H

Hemiſphere, half a globe.
Hermetically ſealed, tube ſealed with melted glaſs.
Hypotheſis, a ſuppoſition.

I

Immerſe, to dip or plunge in.
Impel, to drive onwards.
Incompreſſible, not to be ſqueezed into leſs compaſs.

Incidence, a falling or lighting on.

Inſulate, to cut off, like an iſland

Interſtices, intervals, or intermediate ſpaces.

L

Lateral, ſideway.

Longitudinal, lengthwiſe.

M

Medium, a means of conveyance.

Momentum, the moving force of a body.

O

Oblique, crooked, inclining.

Orbit, the track deſcribed by a planet round the ſun.

P

Particles, exceeding ſmall parts.

Percuſſion, ſtriking, or the effects of a ſtroke.

Perforate, to bore through.

Piſton, a moveable plug, juſt fitting a pipe.

Phænomenon, an appearance in nature.

Phlogiſton, the principle of inflammability in bodies.

Pores, ſmall interſtices in bodies.

Preponderate, to deſcend, be heavier.

Projectile, a body in motion, caſt or thrown.

R

Rarefy, to thin, to make denſe matter weaker.

Reflection, rebounding back, returning.

Reciprocal, mutual, relative.

Refract, to incline, or break.

Reſervoir, a ciſtern, or head for a reſerve of water.

Reverberate, to beat back, to echo.

Rotation, returning about.

S

Saturation, abſorption, drinking in, &c.

Secrete, to ſeparate.

Senſorium, the ſeat of perception in the brain.

Solution, a ſolid diſſolved in a fluid.

Species, ſort or kind.

Specific, peculiar, bulk for bulk

Spiral, like a rope coiled round.

Subterraneous, within the earth.

Sublimation, diſtillation of dry ſubſtances.

Syphon, a bent tube, or crane.

Syſtem, compoſing a general ſtructure.

T

Tangent, a ſtraight line touching the circumference of a circle.

Tangible, capable of being felt or handled.

Tenacity, a clinging together.

Tenſion, a ſtretching out.

Tranſit, the paſſing of a planet before the face of another, or the ſun.

Tube, a pipe.

V

Vacuum, a ſpace devoid of air.

Valve, a trap door, letting a fluid come thro' but not return.

Velocity, the moving ſpeed.

Vertex, the point at the top of any thing.

Vibrate, to ſwing as a pendulum.

Undulating, moving in waves.

Volatile, ſubject to evaporate or fly off.

FINIS.